The effect of cervical spine manipulation compared to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants

By

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I, Sasha Lee King, do hereby declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate the contrary)

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DEDICATION

“Family is one of nature’s masterpieces. They are the compass that guides us, the inspiration to reach great heights and our comfort when we occasionally falter.”

To my parents, Arthur and Ursula King, and my sister, Kendall King, I dedicate this dissertation to you.

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ABSTRACT

Background: Clinical evidence supports the use of spinal manipulative therapy (SMT) and muscle energy technique (MET) for the treatment of cervical spine dysfunctions. However, the physiologic mechanism behind their effectiveness is not well understood. Joint dysfunctions are associated with hypertonicity of segmentally related muscles and can occur in both symptomatic and asymptomatic individuals. Neck pain (NP) has been associated with cervical muscle dysfunction, due to the presence of altered muscle activity and impaired kinematics, demonstrated in NP patients. This includes the upper trapezius and posterior cervical muscles, whose dysfunction can be a source of NP. Spinal manipulative therapy and MET are mechanical interventions, that when applied to joint dysfunctions, produce neurophysiological changes, specifically the modulation of muscle activity and improved range of motion (ROM). However, the demonstration and comparison of the neurophysiological effects of SMT and MET in the neck, and its related musculature, are unknown.

Aim: The aim is to determine the effect of cervical spine manipulation compared to MET on neck muscle activity and range of motion in asymptomatic participants.

Method: This is a quasi-experimental study utilising a pre-test, post-test design, which employed 50 asymptomatic participants aged between 18 – 35 years of both genders and all races. The participants were randomly allocated into one of two treatment groups. Group 1 received cervical spine manipulation (CSM) and Group 2 received MET. Before and after the respective interventions, resting upper trapezius and posterior cervical electromyographic muscle activity and the cervical spine range of motion (CROM) (lateral flexion and extension) were measured. The IBM SPSS version 24 was used to analyse the data. The intra-group changes were compared pre- and post-intervention using paired Wilcoxon signed ranks tests. Median changes between pre- and post- were compared between the two treatment groups using Mann-Whitney U tests. A p value < 0.05 was considered as statistically significant.

Results: None of the demographic or background variables differed significantly between the two groups. Both treatments had an effect, although not all significant, involving

mostly reductions in resting electromyographic muscle activity and improvements in CROM. This was significant for the right posterior cervical muscles in the SMT group ($p = 0.012$) and for ROM in both groups ($p < 0.001$). No evidence of a difference in treatment effect was found.

Conclusion: The results of this study suggest that SMT and MET mostly decrease resting neck muscle activity and improve CROM. Muscle energy technique may possibly be equally as effective as CSM. Concurrent changes in both outcomes suggest that more than one physiologic mechanism may likely explain these effects.

Key indexing terms: *Muscle activity, muscle energy technique, range of motion, spinal manipulative therapy.*

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ABBREVIATIONS AND SYMBOLS

%	**:**	percentage
<	**:**	less than
Ach	**:**	acetylcholine
ATP	**:**	adenosine triphosphate
ATPase	**:**	adensoinetriphosphatase
CDC	**:**	Chiropractic Day Clinic
cm	**:**	centimetre
CN	**:**	cranial nerve
CNS	**:**	central nervous system
CROM	**:**	cervical spine range of motion
CSM	**:**	cervical spine manipulation
DUT	**:**	Durban University of Technology
EMG	**:**	electromyography
EPP	**:**	endplate potential
FRP	**:**	flexion relaxation phenomenon
GTO	**:**	golgi tendon organ
Hz	**:**	Hertz
IREC	**:**	Institutional Research Ethics Committee
IVD	**:**	intervertebral disc
lpc	**:**	left posterior cervical muscles
lut	**:**	left upper trapezius muscles
MEPs	**:**	motor evoked potentials
MET	**:**	muscle energy technique
mVs	**:**	millivolts
n	**:**	sample number
NP	**:**	neck pain
p	**:**	probability
PNS	**:**	peripheral nervous system

RMS : Root mean square

ROM : range of motion

rpc : right posterior cervical muscles

rut : right upper trapezius muscles

SCM : sternocleidomastoid

sEMG : surface electromyography

SMT : spinal manipulative therapy

Std : standard

TMS : transcranial magnetic stimulation

DEFINITIONS

Asymptomatic:
Without symptoms (Venes 2017).

Cavitation:
The formation of vapour and gas bubbles within fluid, through the local reduction of pressure (Bergmann and Peterson 2011).

Interneuron:
Neurons whose axons extend only for a short distance and contact nearby neurons in the brain, spinal cord, or a ganglion; they comprise the vast majority of neurons in the body. They are also called association neurons (Totora and Derrickson 2017).

Joint restriction/ joint dysfunction:
These terms are interchangeable throughout the text. They refer to the state in which an articulation has become temporarily immobilized in a position, which it may normally occupy during any phase of physiologic movement. It is the immobilization of an articulation in a position of movement when the joint is at rest or in a position of rest when the joint is in movement (Bergmann and Peterson 2011).

Motion palpation:
This is a palpatory diagnosis of passive and active segmental joint range of motion (Bergmann and Peterson 2011).

Motor neuron:
Motor neurons are neurons that conduct impulses from the brain toward the spinal cord, or out of the brain and spinal cord into the cranial, or spinal nerves, to effectors that may be either muscles or glands. They are also called efferent neurons (Totora and Derrickson 2017).

Muscle activity:

This is a random, detached firing of groups of muscle fibres (Criswell 2011).

Muscle energy technique:

This technique is a manual medicine treatment procedure that involves the voluntary contraction of patient muscles in a precisely controlled direction, at varying levels of intensity, against a distinctly executed counterforce applied by the operator (DeStefano 2017).

Range of motion:

Range of motion is the range of translation and rotation of a joint for each of its six ranges of freedom (Bergmann and Peterson 2011).

Sensory neuron:

A sensory neuron carries sensory information from cranial and spinal nerves into the brain and spinal cord or from a lower to a higher level in the spinal cord and brain. It is also called an afferent neuron (Totora and Derrickson 2017).

Spinal manipulative therapy:

Broadly defined, this includes all procedures in which the hands are used to mobilize, adjust, manipulate, apply traction to, massage, stimulate, or otherwise influence the spine and paraspinal tissues, with the aim of influencing a patient's health. This is a manual procedure that involves a directed thrust to move a joint past the physiologic range of motion without exceeding the anatomic limit (Bergmann and Peterson 2011).

Surface electromyography:

Surface electromyography is the use of surface electrodes for the recording of electrical potentials from the underlying musculature. It is used in the study of posture, movement, and emotional expression. The record is typically inspected for evidence of the following: emotional lability, antalgic postures, splinting, guarding, co-contractions, symmetries and asymmetries, flexion–relaxation, and other recruitment patterns (Criswell 2011).

CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

Neck pain (NP) is the world's leading cause of years lived with disability (Global Burden of Disease 2015 Disease and Injury Incidence and Prevalence Collaborators 2016). According to Hoy, Protani and Buchbinder (2010), the mean overall prevalence of NP in the general population is 23.1%, with an estimated one-year incidence ranging between 10.4% and 21.3%. South African studies conducted in the various demographic groups on the prevalence of NP revealed that NP was experienced in almost half of each population (Ndlovu 2006; Slabbert 2010; Muchna 2011). The prevalence of NP is said to increase with age, with a peak in the middle years, and then with a decline in later life (Hoy, Protani and Buchbinder 2010). Generally, women have more NP than men (Fejer, Kyvik and Hartvigsen 2006; Cohen 2015).

Cohen (2015) states that most patients who present with NP have non-specific or mechanical NP. Mechanical NP refers to generalized NP that is attributed to mechanical dysfunctions of the cervical spine (Fernández-de-las-Peñas, Downey and Miangolarra-Page 2005). Symptoms of NP are provoked by maintained misaligned neck postures, neck movement or by palpation of the cervical muscles (Cohen 2015; Phadke *et al*. 2016). The source of symptoms is not completely understood, but it is thought to be related to various anatomical structures, particularly the zygapophyseal or uncovertebral joints and myofascial structures of the cervical spine (Cohen 2015; Phadke *et al*. 2016).

Cervical joint dysfunction is defined as a temporary reduction in mobility of a cervical segment (Fernández-de-las-Peñas, Downey and Miangolarra-Page 2005). According to Bergmann and Peterson (2011), a joint dysfunction can result from an array of factors, including acute injury, repetitive-use injury, faulty posture or coordination and static overstress. Fryer (2016) highlights that a joint dysfunction is not synonymous with spinal pain, and palpable signs of dysfunction may be detected in both symptomatic and asymptomatic individuals. It has been proposed that the presence of joint

dysfunctions in asymptomatic individuals creates biomechanical and neurological consequences, which predisposes the individual to pain and other health complaints (Fryer 2016). Intervertebral hypomobility is considered the cardinal feature of a joint restriction (Henderson 2012). This produces a biomechanical overload which can alter the signalling properties of mechanically sensitive neurons in paraspinal tissues. This change in sensory input can create changes in muscle activity (Pickar 2002).

The upper trapezius and posterior cervical muscles provide the forces necessary for movement, postural support and primary stability of the cervical region (Bergmann and Peterson 2011). Articular dysfunction in the cervical spine is associated with the dysfunction of these muscles (Fernández de las Peñas, Cleland and Huijbregts 2011). This can predispose healthy individuals to the development of NP (O'Leary *et al*. 2009). Altered activation of the neck muscles is a well-known feature of NP (Lindstrom *et al*. 2011). It has been demonstrated that NP patients are unable to fully relax their cervical extensor muscles and display increased muscle activity during full forward cervical flexion (Maroufi, Ahmadi and Khatir 2013). This may be necessary to protect the spine from further injury. In addition, individuals with NP have increased activity of the upper trapezius, in most movements of the cervical spine, which may result in greater loading, mostly compressive, of the cervical spine (Castelein *et al*. 2015; Lascurain-Aguirrebeñ *et al*. 2018).

Spinal manipulative therapy is the specific and effective treatment for joint dysfunctions and is the focus of chiropractic care (Bergmann and Peterson 2011; Fryer 2016). It has multiple benefits that include decreased pain, restored range of motion (ROM), increased pain pressure thresholds and reduced zygapophyseal joint effusion and peri-articular oedema (Suter *et al*. 2000; Hamilton, Boswell and Fryer 2007; Gross *et al*. 2010). Moreover, SMT has been proposed to produce neurologic changes to influence muscle relaxation, proprioception and motor control (Fryer and Pearce 2012).

Little is known about the detailed mechanism through which SMT achieves its therapeutic effects (Currie *et al*. 2016). Potter, McCarthy and Oldham (2005) suggest that this may occur through biomechanical, muscular reflexogenic and/or neurophysiological mechanisms. Improving the understanding of how these

mechanisms are related to clinical conditions may provide additional insights into the mechanism of SMT as a treatment, as experimental evidence of its effectiveness is lacking (Cardinale *et al*. 2015).

Most chiropractic patients receive SMT as part of their chiropractic care (Pickar and Kang 2006). However, when SMT is contraindicated, other techniques are used, such as MET (Liebenson 2007). Franke *et al*. (2016) described MET as a manual therapy treatment technique predominantly used by osteopaths, physiotherapists and chiropractors. It has been proposed to mobilise a restricted joint, lengthen a shortened muscle, strengthen a weakened muscle and reduce localised oedema (Fryer and Pearce 2013). Hamilton, Boswell and Fryer (2007) highlight that MET differs to SMT in that it is a patient-initiated contraction, and thus the patient is allowed complete control over the treatment which contributes to the corrective force. As with SMT, the mechanism responsible for the therapeutic effects of MET are unclear and proposed mechanisms are largely speculative (Fryer 2011).

Clinical evidence supports the use of SMT and MET for the treatment of cervical spine dysfunction (Wood, Colloca and Matthews 2001; Hurwitz *et al*. 2002; Gemmell and Miller 2006; Gross *et al*. 2010). However, the mechanism behind their effectiveness is not well understood. Spinal manipulative therapy and MET are mechanical treatments associated with neurophysiological changes, but, this has yet to be demonstrated and compared in the neck and its related musculature. Studying the effects of these interventions on asymptomatic individuals may offer further insights into the neurophysiological muscle response of SMT and MET, without the confounding, uncontrolled effects of altered muscle activation related to pain (Grindstaff *et al.* 2009). Understanding these effects may assist an evidence-informed approach to technique selection (Fryer 2011).

1.2 RESEARCH PROBLEM

The physiological mechanisms behind the effectiveness of SMT and MET are only theoretical at present, but clinical evidence supports their use in the treatment of cervical spine dysfunction (Wood, Colloca and Matthews 2001; Hurwitz *et al*. 2002;

Gemmell and Miller 2006; Gross *et al*. 2010). Joint dysfunctions can occur in both symptomatic and asymptomatic individuals. When joint dysfunctions are present, there is a hyperactivity of segmentally related muscles (Haavik and Murphy 2012). Studies have demonstrated that SMT and MET reduce the muscle activity of hypertonic muscles. Yet, the literature describing and comparing the neurophysiological effects of SMT and MET in the neck are limited. Therefore, this study will determine the effect of CSM, compared to MET, on neck muscle activity and ROM in asymptomatic participants.

1.3 STUDY RATIONALE

Spinal manipulative therapy and MET are manual therapeutic interventions utilised by chiropractors (Liebenson 2007). These interventions differ in application, even though both of these target restricted or dysfunctional joints to restore maximum pain free movement (Hamilton, Boswell and Fryer 2007). It has been demonstrated that when joint dysfunctions are present, there is hyperactivity of segmentally related muscles (Haavik and Murphy 2012). When assessing the effects of SMT and MET on muscle activity, studies have indicated a decrease in surface electromyographic activity, alpha motoneuron activity or overall motor excitability in healthy individuals (Herzog, Scheele and Conway 1999; Dishman and Bulbulian 2000; Fryer and Pearce 2013). Those studies suggest that SMT and MET can produce a reduction in muscle activity. However, there is paucity in the literature describing and comparing the effect of SMT and MET on neck muscle activity.

According to Binder (2007), NP is the second most common musculoskeletal complaint worldwide. In South Africa, NP is the second leading cause of years lived with disability (Global Burden of Disease 2015 Disease and Injury Incidence and Prevalence Collaborators 2016). The symptoms of NP are said to have a postural or mechanical basis where postural muscles, which include the upper trapezius and posterior cervicals, have important roles in postural support, where their dysfunction results in NP (Yadav and Goyal 2015). Neck pain sufferers demonstrate an inability to completely relax the cervical extensor muscles and have increased muscle activity during full

forward cervical flexion (Maroufi, Ahmadi and Khatir 2013). In addition, individuals with NP have an increased activity of the upper trapezius in most movements of the cervical spine (Lascurain-Aguirrebeñ *et al.* 2018). Thus, NP is associated with altered muscle activity and impaired kinematics (Cheng *et al.* 2014; Treleaven, Chen and Bahat 2016).

Spinal manipulative therapy and MET have been shown to be effective in the conservative management of musculoskeletal disorders, such as NP (Hurwitz *et al.* 2002; Gemmell and Miller 2006; Gross *et al.* 2010). In fact, studies have shown SMT and MET to have measurable clinical changes in terms of pain, tenderness and ROM (Cassidy, Lopes and Yong-Hing 1992; Hamilton, Boswell and Fryer 2007; El Gendy *et al.* 2017). Despite the clinical evidence for the benefits and wide usage of these interventions, there is a lack of understanding of how these therapeutic effects are achieved (Fryer 2011; Currie *et al.* 2016). According to Potter, McCarthy and Oldham (2005), there is evidence in literature to suggest that SMT exerts its effects by means of biomechanical, muscular reflexogenic and neurophysiological mechanisms, in which SMT may exerts its physiological influence by a combination of these effects. Similarly, Fryer (2011) states that the underlying therapeutic action of MET may involve a variety of neurological and biomechanical mechanisms.

This study, therefore, aims to determine the effect of SMT, compared to MET, on neck muscle activity and ROM in asymptomatic participants. Studying the effects of these interventions on asymptomatic individuals may provide additional insight, without the confounding, uncontrolled effects of altered muscle activation related to pain (Grindstaff *et al.* 2009). An understanding of the possible physiological therapeutic mechanisms underlying manual techniques may assist an evidence-informed approach to technique selection (Fryer 2011). In order to do so, it has been suggested that studies should evaluate the usefulness of MET in treating spinal dysfunction (Chaitow 2006) and experimental work regarding the neurophysiological effects of SMT should be conducted (Pickar 2002). This will add to the body of literature regarding how the neurophysiological effects of SMT and MET affect muscle activity and joint dysfunction.

1.4 AIMS AND OBJECTIVES

1.4.1 Aim

The aim of the study was to determine the effect of cervical spine manipulation, compared to muscle energy technique, on neck muscle activity and range of motion in asymptomatic participants.

1.4.2 Objectives

Objective One

To determine the effects of cervical spine manipulation on the surface electromyographic muscle activity of the posterior cervical and upper trapezius muscles, and the cervical range of motion (extension and lateral flexion).

Objective Two

To determine the effects of muscle energy technique on the surface electromyographic muscle activity of the posterior cervical and upper trapezius muscles and the cervical range of motion (extension and lateral flexion).

Objective Three

To compare and correlate the data (surface electromyographic muscle activity and cervical range of motion) between the two intervention groups, i.e. to assess whether changes from baseline in outcomes are correlated within treatment groups and between treatment groups.

1.5 HYPOTHESES

1.5.1 Null Hypothesis

In the absence of consistent findings from the available literature comparing the effect of cervical spine manipulation to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants, the following null hypothesis was set prior to the onset of the work: There will be no differences between the cervical spine

manipulation and muscle energy technique treatment groups in terms of surface electromyographic activity and cervical range of motion.

1.5.2 Alternate Hypothesis

The following one directional hypothesis was set with respect to the null hypothesis: There will be a statistically significant difference between the cervical spine manipulation and muscle energy technique treatment groups in terms of surface electromyographic activity and cervical range of motion.

1.6 CONCLUSION

This chapter has presented the problem and its setting and motivated the importance of the research study. Chapter two highlights the literature surrounding the research problem, with particular interest in the theories describing the effects of SMT and MET. Chapter three describes the methodology of the study including the measurement tools and interventions used. Chapter four presents the results obtained in the study, and this is followed by chapter five, which discusses the results and their contexts, when comparing and contrasting them with the available literature. Chapter six provides recommendations for future research and draws the final conclusions of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents the anatomy of the cervical spine, and an overview of the nervous system and skeletal muscle physiology. The relationship between joint fixations and muscle activity shall be discussed, which is then linked to the theories explaining the effects of spinal manipulative therapy and muscle energy technique. The literature relating to the research question will also be reviewed.

2.2 OVERVIEW OF THE NECK

The neck is the transitional area between the base of the cranium superiorly and the clavicles inferiorly. It joins the head to the trunk and limbs, serving as a major conduit for structures passing between them (Moore, Dalley and Agur 2014). The bones present in the neck form the cervical spine. The cervical spine is the most superior and agile part of the human spine. The cervical spine consists of seven vertebrae that enclose the spinal cord and meninges and forms a lordotic curve. The stacked, centrally-placed vertebral bodies support the head, and the intervertebral articulations provide the flexibility necessary to allow positioning of the head. (Moore, Dalley and Agur 2014; Galbusera and Wilke 2018).

2.2.1 Cervical Vertebrae

The cervical vertebrae are divided into typical (C3 - C6) and atypical (C1, C2 and C7) vertebrae. The four typical cervical vertebrae share the following similar anatomic features (Bergmann and Peterson 2011; Moore, Dalley and Agur 2014):

- The vertebral body has anterior and posterior surfaces that are small, oval and wide, transversely. The superior surface is concave and the inferior surface is convex. The posterolateral aspect of the superior margin of the vertebral body is lipped, forming the uncinate processes. These serve to strengthen and stabilize the region.

- The spinous processes are bifid to allow for better ligamentous and muscular attachment.
- The transverse process of all cervical vertebrae, typical or atypical, include oval transverse foramina for the passage of the vertebral veins and, except for vertebra C7, the vertebral arteries.
- The articular facets are teardrop-shaped and are most nearly horizontal in this region. The superior facets of the articular processes are directed superoposteriorly and the inferior facets are directed inferoanteriorly.
- The short and round pedicles are directed posterolaterally. The laminae are long, narrow, slender and sloping.
- The vertebral foramen is large and triangular.

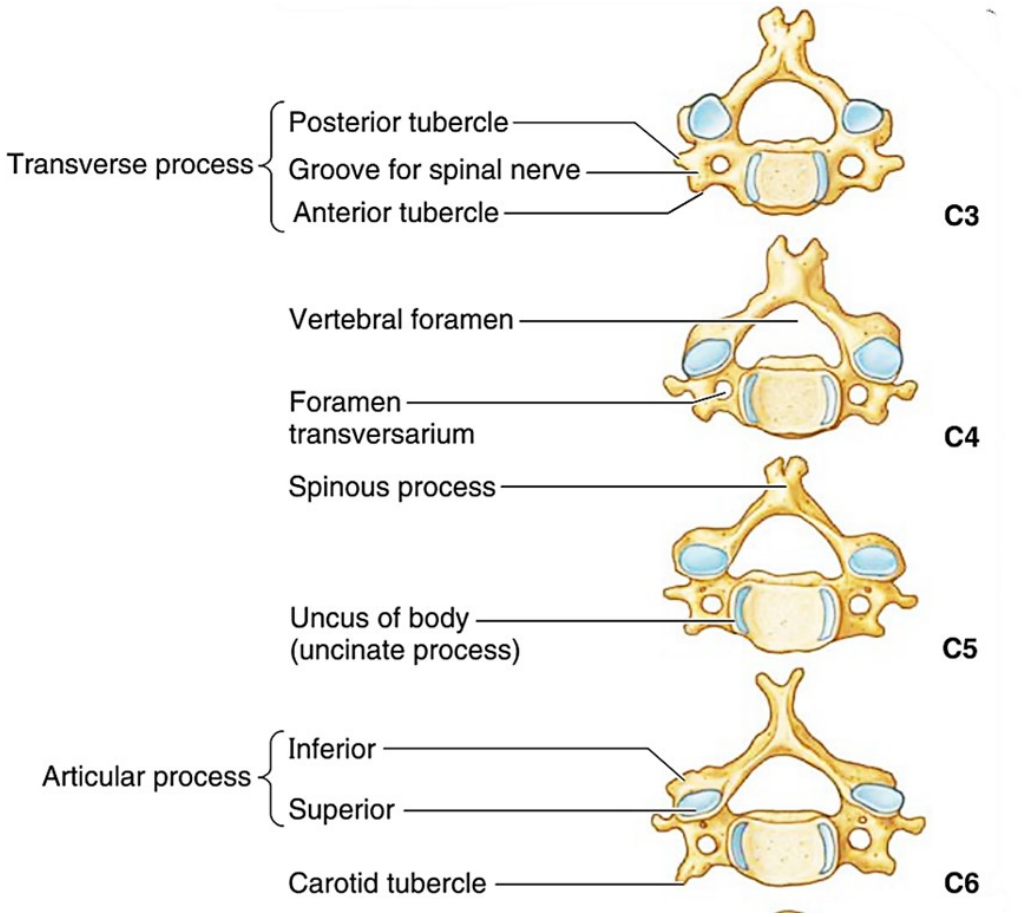

Figure 2.1 Superior view of the typical cervical vertebrae (Moore, Dalley and Agur 2014)

Each of the three atypical cervical vertebrae possess unique anatomic features:

- The C1 vertebra or atlas is a ring-like, kidney-shaped bone lacking a spinous process or body, with two lateral masses connected by anterior and posterior arches. The lateral masses have concave superior articular facets for articulation with the occipital condyles, and circular inferior facets for articulation with the axis (Bergmann and Peterson 2011; Moore, Dalley and Agur 2014).

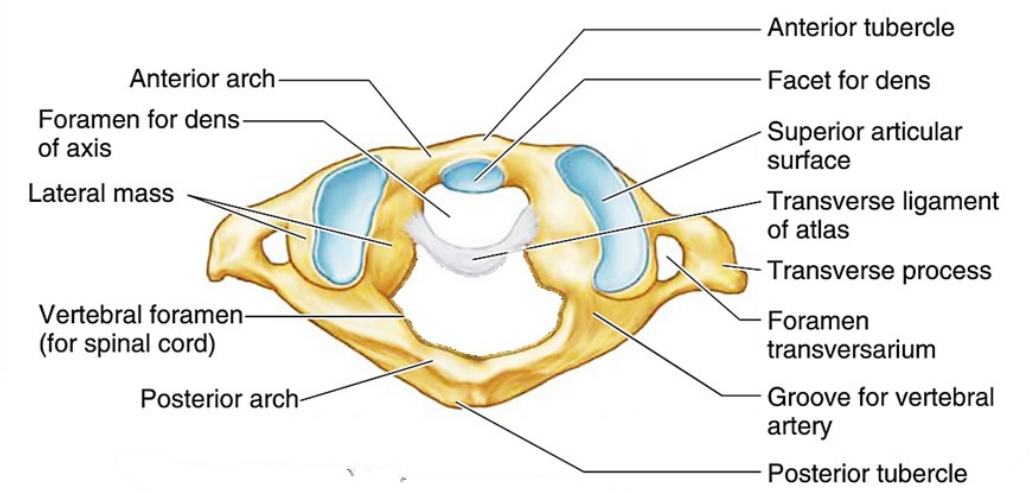

Figure 2.2 Atlas (C1 vertebra) (Moore, Dalley and Agur 2014)

- In the C2 vertebra or axis, a blunt, tooth-like dens or odontoid process projects superiorly from its body and is its most characteristic feature. The spinous process of the axis is large and bifid, and it is the first palpable midline structure below the occiput (Bergmann and Peterson 2011; Galbusera and Wilke 2018).

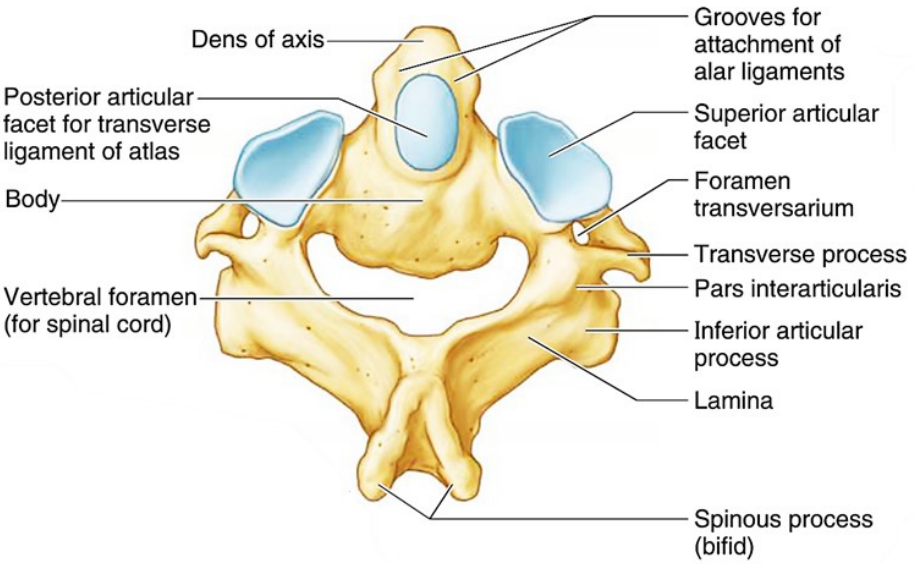

Figure 2.3 Axis (C2 vertebra) (Moore, Dalley and Agur 2014)

- The C7 vertebra, or vertebra prominence is so named, according to Moore, Dalley and Agur (2014), due to its long and slender spinous process. According to Galbusera and Wilke (2018), the spinous process of C7 is the longest along the entire spine. This vertebra has no uncinate processes. The transverse processes are large, broad and blunt, and its transverse foramina are smaller than those in other cervical vertebrae and occasionally are absent. (Bergmann and Peterson 2011).

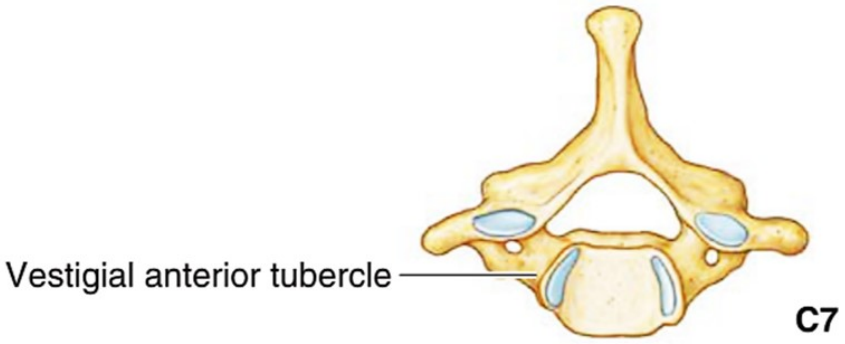

Figure 2.4 Vertebra prominence (C7 vertebra) (Moore, Dalley and Agur 2014)

2.2.2 Articulations of the Cervical Spine

2.2.2.1 Intervertebral Discs

The intervertebral discs (IVDs) of the cervical spine constitute more than 25% of the superior to inferior length of this region, and here, the IVDs are thicker anteriorly. They provide strong attachments between the vertebral bodies, uniting them into a continuous semi-rigid column and forming the inferior half of the anterior border of the intervertebral foramen. The IVDs help to allow the large amount of motion that occurs between adjacent cervical vertebrae. In addition, their resilient deformability allows them to serve as shock absorbers. They are not present between the atlas and axis, and thus the C2-3 interbody is the first such joint to possess an IVD. Each IVD consists of an outer fibrous part, called the annulus fibrosis, and a gelatinous central mass, called the nucleus pulposus. The annulus fibrosis is a bulging fibrous ring consisting of concentric lamellae of fibrocartilage, forming the circumference of the IVD. Only the outer third of the annulus receives sensory innervation. The nucleus pulposus is the core of the disc. The nucleus pulposus is avascular. It receives its nourishment from a diffusion from blood vessels at the periphery of the anulus fibrosus and the vertebral body (Cramer and Darby 2014; Moore, Dalley and Agur 2014).

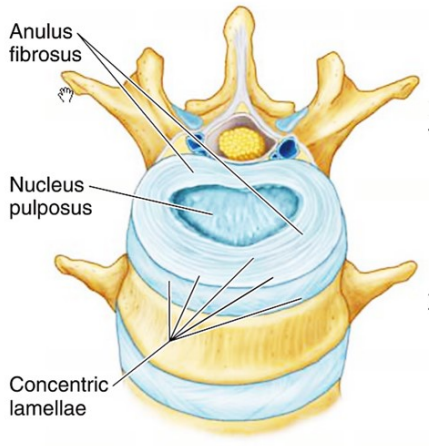

Figure 2.5 Transverse section of an intervertebral disc (Moore, Dalley and Agur 2014)

2.2.2.2 Craniovertebral Joints

There are two sets of craniovertebral joints. They serve as a transition from the skull to the rest of the spine and are the most complex articulations of the axial skeleton (Magee

2008; Bergmann and Peterson 2011). These include the atlanto-occipital and atlanto-axial joints. The atlanto-occipital joints (C0 – C1) are freely movable synovial condyloid joints, formed between the superior articular surfaces of the lateral masses of the atlas and the occipital condyles. Its principal movements are flexion, extension and lateral flexion (Magee 2008; Bergmann and Peterson 2011; Moore, Dalley and Agur 2014).

The atlanto-axial joints (C1 – C2) are formed by the articular surfaces of the atlas and the axis. There are three atlanto-axial articulations, two lateral and one median. The lateral atlanto-axial joints are gliding-type synovial joints formed by the lateral mass of the atlas and the axis. The median atlantoaxial joint is a pivot joint formed between the posterior surface of the anterior arch of the atlas and the anterior aspect of the odontoid process, and the anterior surface of the transverse ligament and the posterior aspect of the odontoid process. Rotation is the primary movement of these joints (Magee 2008; Bergmann and Peterson 2011).

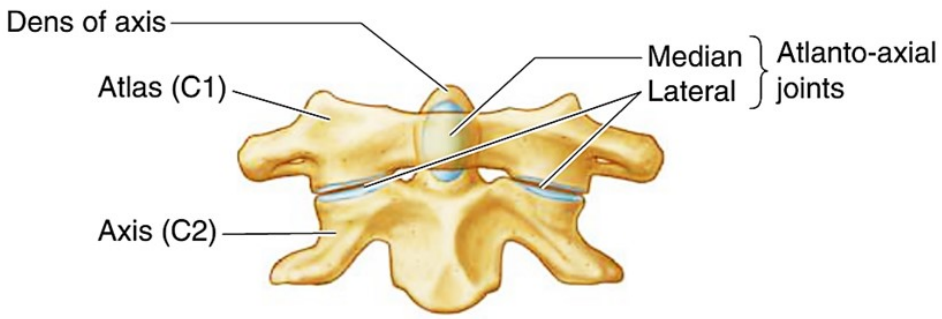

Figure 2.6 Three atlanto-axial joints (Moore, Dalley and Agur 2014)

2.2.2.3 Uncovertebral "Joints"

Uncovertebral "joints", or joints of Luschka, are formed between the uncinate processes of the vertebral bodies of C3 or C4, to C6 or C7 vertebrae and the inferolateral surfaces of the vertebral bodies superior to them. The uncovertebral articulations are pseudojoints that have a synovial membrane with synovial fluid but no joint capsule (Moore, Dalley and Agur 2014). They allow for flexion and the extension of the cervical spine and help to limit lateral flexion (Cramer and Darby 2014).

2.2.2.4 Facet Joints

The facet, or zygapophyseal, joints are plane synovial joints between the superior and inferior articular processes of adjacent vertebrae (Galbusera and Wilke 2018). They lie approximately 45 degrees to the horizontal plane. The zygapophyseal joints permit gliding movements between the articular processes (Moore, Dalley and Agur 2014). Each joint is surrounded by a thin joint capsule, which in the cervical spine is thinner and looser than in the rest of the spine, to compensate for the greater amount of movement that occurs in the cervical spine. The joint capsule is attached to the margins of the articular surfaces of the articular processes of adjacent vertebrae. Together with the IVD, they form a flexible connection of the cervical vertebrae and at the same time prevent the cervical spine from making extensive movements that could potentially damage the spinal cord. (Cramer and Darby 2014; Galbusera and Wilke 2018).

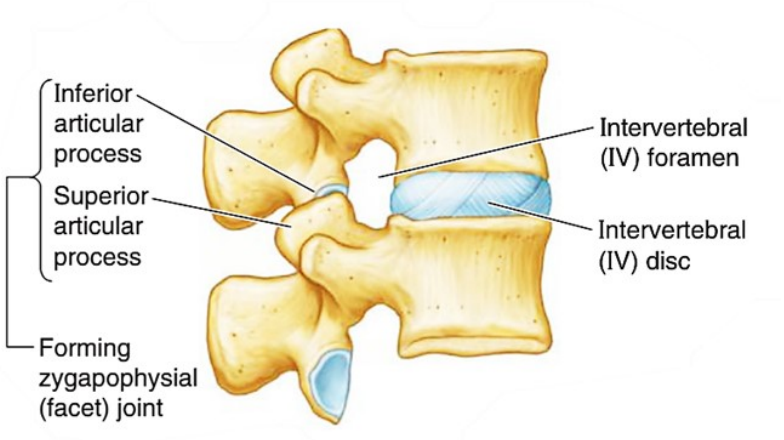

Figure 2.7 Zygapophyseal joints (Moore, Dalley and Agur 2014)

The zygapophyseal joint capsule receives a rich supply of sensory innervation. This supply is derived from the medial branches of the posterior rami of spinal nerves at the level of the joint, as well as the level above (Gatterman 2005; Cramer and Darby 2014). In addition, Wyke (1987) states that there are three types of sensory receptors in the joint capsule of the zygapophyseal joints. They are characterized according to their function:

- Type I – very sensitive, static and dynamic mechanoreceptors, that fire continually to some extent, even when the joint is not moving.
- Type II – less sensitive and fire only during movement.
- Type III - sensory receptors are nociceptive fibres found in joints of extremities, which Wyke (1987) did not find in the zygapophyseal joints.
- Type IV – slow conducting nociceptive mechanoreceptors.

The three types of mechanoreceptors situated in the cervical facet joints function to ensure proper alignment of the vertebrae in the cervical spine.

2.2.3 Muscle Overview

Cramer and Darby (2014) state that the musculature of the spine plays an important role in the normal functioning of the vertebral column. In addition to their ability to create a variety of spinal movements, muscle contraction stabilizes the spine by making it stiffer. This is important not only for maintaining posture, but for providing a stable base for other movements to occur. The cervical spine is an area in which stability is sacrificed for mobility, making it particularly vulnerable to injury (Magee 2008). Thus, eighty percent of cervical spine stability is provided by the muscles surrounding the neck (Tsang, Szeto and Lee 2014). The upper trapezius and posterior cervical muscles provide the forces necessary for movement, postural support and primary stability of the cervical region (Bergmann and Peterson 2011).

2.2.3.1 The Trapezius Muscle

Cramer and Darby (2014) state that the trapezius muscle is the most superficial and superior back muscle. It is a large, flat triangular muscle that receives motor innervation from the spinal accessory nerve (cranial nerve XI) and pain and proprioceptive fibres, from C3 and C4 spinal nerves (Moore, Dalley and Agur 2014). Due to the large size of this muscle, it has many attachment sites, and consequently many actions, most of which result in movement of the neck and scapula.

The trapezius can be divided into three distinct fibre directions: the upper, middle and lower fibres. Their anatomy is described by Simons, Travell and Simons (1999) and Moore, Dalley and Agur (2014) as upper fibres which have a descending fibre

orientation and originate from the medial third of the superior nuchal line, external occipital protuberance and the nuchal ligament. The fibres converge anterolaterally to attach to the posterior border of the lateral third of the clavicle. When acting unilaterally, the upper trapezius fibres extend and laterally flex the head and neck ipsilaterally, and aid in extreme contralateral rotation of the head. The upper trapezius can draw the clavicle posteriorly and elevate the clavicle by rotating the clavicle at the sternoclavicular joint. The upper trapezius also assists in elevating and rotating the glenoid fossa upward. Acting bilaterally, the upper fibres extend the head and neck.

The nearly horizontal middle fibres originate from the spinous processes and interspinous ligaments of C6 to T3 vertebrae, and attach laterally to the medial margin of the acromion and superior lip of the spine of the scapula. These fibres effectively retract the scapula.

The lower fibres have an ascending fibre direction and originate from the spinous processes and interspinous ligaments of T4 to T12 vertebrae. Laterally, they converge and attach in the region of the tubercle, at the medial end of the spine of the scapula. The lower trapezius fibres retract and depress the scapula, and rotate the glenoid fossa superiorly.

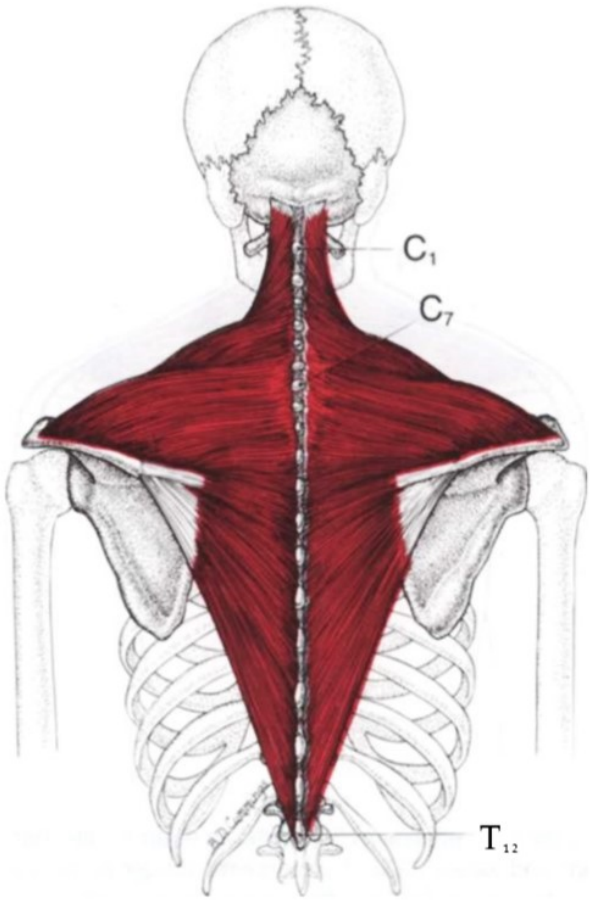

Figure 2.8 The trapezius muscle (Simons, Travel and Simons 1999)

2.2.3.2 The Posterior Cervical Muscles

The posterior cervical muscles are divided anatomically into three layers according to their relationship to the surface. They all receive innervation from the posterior rami of spinal nerves. Their anatomy is described according to Simons, Travell and Simons (1999) and Moore, Dalley and Agur (2014). The superficial layer consists of the thick and flat splenius muscles. Splenius capitis and splenius cervicis both originate from the nuchal ligament and spinous processes of C7 to T6 vertebrae. The fibres of splenius capitis run superolaterally to attach to the mastoid process and the lateral third of the superior nuchal line. The splenius cervicis attaches to the tubercles of the transverse processes of C1 to C3 or C4 vertebrae. When acting alone, these muscles laterally flex

the neck and rotate the head to the contralateral side and when acting together, extend the head and neck.

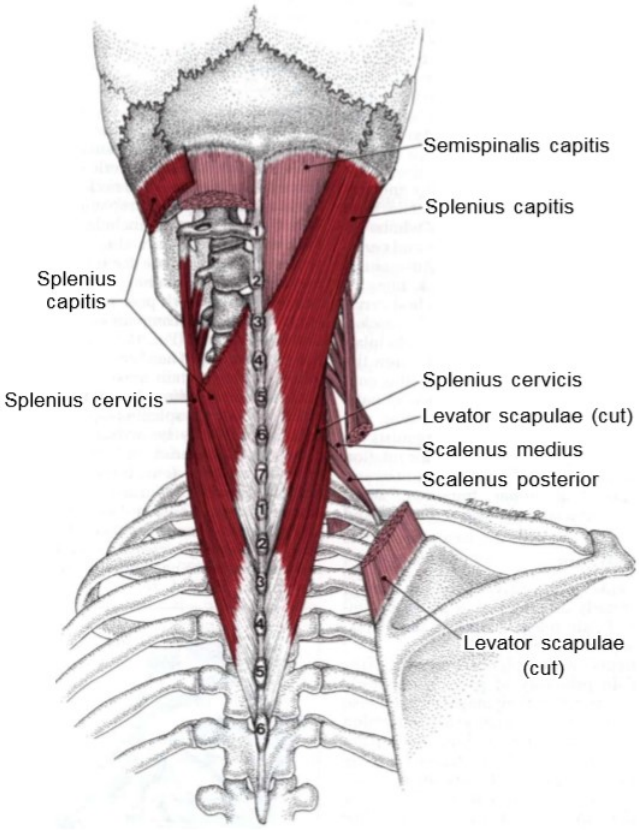

Figure 2.9 Superficial layer of posterior cervical muscles (splenius muscles) (Simons, Travel and Simons 1999)

The intermediate layer consists of the longissimus capitis. This muscle originates from the articular processes of C4 or C5 to C7 vertebrae and the transverse processes of T1 to T4 or T5 vertebrae. It attaches to the posterior margin of the mastoid process, deep to the splenius capitis. When acting bilaterally, the longissimus capitis extends the vertebral column and head and when acting unilaterally, laterally flexes the vertebral column and rotates the head to the ipsilateral side.

The deep layer consists of much shorter muscles: the semispinals, multifidus and rotatores. The semispinalis capitis and cervicis are the superficial muscles of this layer.

The semispinalis capitis originates from the articular processes of C4 to C6 vertebrae and transverse processes of T1 to T6 and sometimes T7 vertebrae. It runs superomedially to attach above to the occiput between the superior and inferior nuchal lines. The semispinalis has one main action, extension of the head, and it functions in antigravity control of the head when one leans forward. The semispinalis cervicis lies deep to the semispinalis capitis and originates from the transverse processes of T1 to T5 or T6 vertebrae. Above, it attaches to the spinous processes of the second to fifth cervical vertebrae. Toward its cephalic end, it becomes thicker and more muscular. This muscle is reported to primarily extend the cervical spine and to rotate it to the contralateral side. The caudal attachments of this muscle, to the relatively immobile thoracic vertebrae, serve primarily as anchors for movement of the cervical spine.

The cervical multifidi are the middle muscles of the deep layer and consist of short, triangular muscle bundles. The cervical multifidi originate from the spinous processes of vertebrae C2 to C5. The fibres then pass superomedially to attach to the articular processes of C4 to C7; multifidi fibres cross two to four vertebrae. This muscle functions to stabilize and steer the cervical spine during local movements of the cervical spine.

The cervical rotatores are the deepest of the three layers. The cervical rotatores begin at the transverse processes of C2 and continue downward, segmentally. The fibres pass superomedially to attach to the junction of the lamina and transverse process or spinous process of vertebra immediately, or two segments superior, to the vertebra of attachment. They are the shortest and deepest paraspinal muscles and connect to adjacent or alternate vertebrae and, therefore, are angulated. The cervical rotatores stabilize the vertebrae and assist with local extension and rotatory movements of the cervical spine.

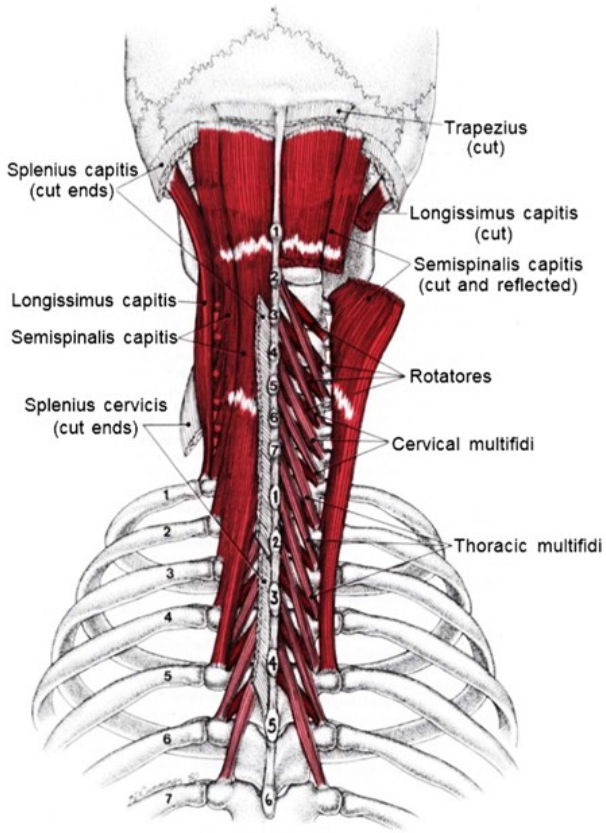

Figure 2.10 Intermediate and deep layer of the posterior cervical muscles (longissimus, semispinalis, multifidus and rotatores) (Simons, Travel and Simons 1999)

According to Cramer and Darby (2014), muscle co-ordination is under the control of the central nervous system (CNS). The CNS is constantly receiving information from muscles and other surrounding tissues, such as ligaments and tendons. Based on this information, the CNS uses reflex pathways to finely control muscle activity.

2.3 OVERVIEW OF THE NERVOUS SYSTEM

The nervous system is the chief organ system that correlates adjustments and reactions of the body to the conditions of the internal and external environment. Anatomically, the nervous system is divided into the central and peripheral nervous systems. The CNS consists of the brain and spinal cord, lying within the protection of the cranium and vertebral column, respectively. The peripheral nervous system (PNS)

is divided into the somatic nervous system, autonomic nervous system and enteric nervous system and it is the means by which the CNS communicates with its surrounding environment (Moore, Dalley and Agur 2014; Crossman and Neary 2015).

2.3.1 The Peripheral Nervous System

The PNS consists of peripheral nerves, collections of nerve cell bodies known as ganglia, and specialized nerve endings. A nerve is a bundle of hundreds, to thousands, of axons and associated connective tissue and blood vessels that lie outside the brain and spinal cord (Tortora and Derrickson 2017). The peripheral nerves comprise the cranial and spinal nerves linking the brain and spinal cord to the peripheral tissues. There are twelve pairs of cranial nerves (CN), most of which innervate structures in the head and convey special sense information, such as hearing, vision, smell and taste. The exceptions are CN X, which receives sensory information from the thoracic and abdominal viscera, and CN XI which innervates the sternocleidomastoid (SCM) and trapezius muscles (Cramer and Darby 2014).

The spinal nerves are responsible for connecting the CNS to sensory receptors found throughout the body in skin, muscles, tendons, joints and viscera and effector organs, which are muscle tissue and glands (Cramer and Darby 2014). Spinal nerves are identified by a letter and number, designating the region and level of the spinal cord from which they emerge. They initially arise from the spinal cord as rootlets that converge to form an anterior (ventral) and posterior (dorsal) nerve root. The ventral root contains fibres that convey motor information to the body's effectors and the dorsal root contains fibres, that convey sensory information (FitzGerald, Gruener and Mtui 2012; Moore, Dalley and Agur 2014).

The dorsal and ventral nerve roots unite, within, or just proximal, to the intervertebral foramen, to form a one centimetre long mixed spinal nerve. On emerging from the foramen, it divides into anterior and posterior rami. As branches of the mixed spinal nerve, the posterior and anterior rami carry both motor and sensory fibres, as do all their subsequent branches. The posterior rami supply nerve fibres to the synovial joints of the vertebral column, deep muscles of the back and the overlying skin of the trunk. The anterior rami supply the anterior and lateral regions of the trunk and the upper and

lower limbs. In order to supply the upper and lower limbs, the majority of anterior rami merge with one or more adjacent anterior rami to form the cervical, brachial, lumbar and sacral plexuses (networks) (FitzGerald, Gruener and Mtui 2012; Moore, Dalley and Agur 2014).

The spinal nerve also gives off a meningeal branch (recurrent meningeal/ sinuvertebral nerve) that arises immediately after it is formed and before it divides into anterior and primary rami, or from the anterior ramus immediately after its formation. As the spinal nerves exits the intervertebral foramina, most of the meningeal branches run back through the foramina into the vertebral canal to supply the periosteum, ligamentum flava, annuli fibrosis of the posterior and posterolateral aspect of the IVDs, posterior longitudinal ligament, spinal dura mater and blood vessels within the vertebral canal. Some branches remain outside the vertebral canal and are distributed to the anterolateral aspect of the vertebral bodies and IVDs (Moore, Dalley and Agur 2014).

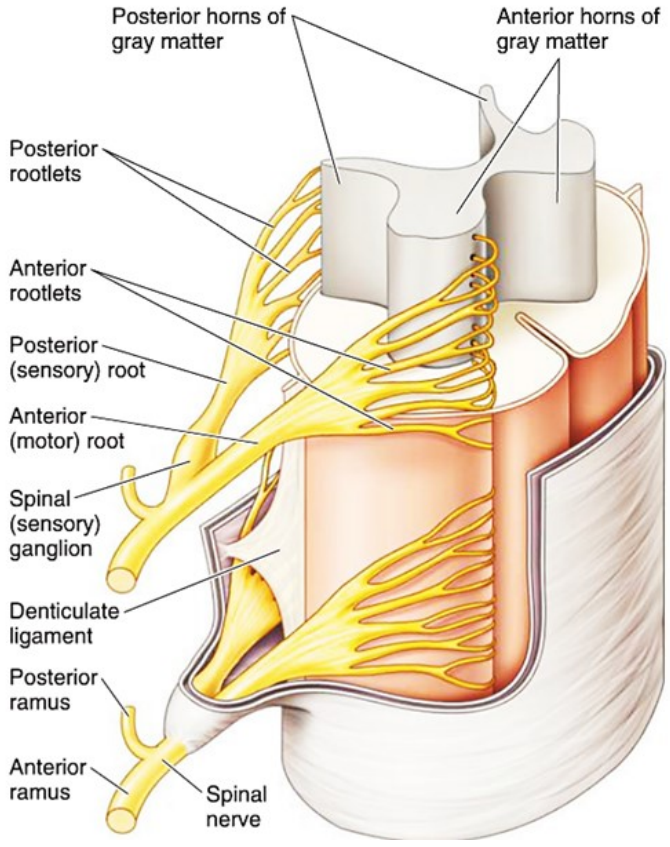

Figure 2.11 Spinal nerve (Moore, Dalley and Agur 2014)

2.3.2 Nerve Types

Peripheral nerve fibres are divided into sensory neurons, motor neurons and interneurons. A neuron, or nerve cell, is the basic structural and functional unit of the nervous system. Neurons function by generating electrical signals, called action potentials. Action potentials are transient depolarizations of the cell membrane of the neuron. Action potentials allow rapid intercellular communication at specialized junctions, known as synapses. Neurons contain ion channels within the cell membrane. In the resting state, this cell membrane is relatively impermeable to ions. The neuronal cell membrane can be opened by either changing the voltage across the cell membrane or by binding of a chemical messenger, called a neurotransmitter, to a receptor in, or near, the ion channel. In the PNS, the neurotransmitter is called acetylcholine (Ach). Opening the ion channels allow an influx of sodium. This depolarizes the membrane, forming an action potential that is transmitted rapidly down the axon (Widmaier, Raff and Strang 2011; Cramer and Darby 2014).

Sensory or afferent neurons are described in Table 2.1. They either contain sensory receptors at their distal ends or are located just after sensory receptors, which are separate cells. Once an appropriate stimulus activates a sensory receptor, the sensory neuron forms an action potential in its axon and the action potential is conveyed into the CNS through cranial or spinal nerves. The cell bodies of sensory neurons lie in the dorsal root ganglion (Widmaier, Raff and Strang 2011; Tortora and Derrickson 2017).

Table 2.1 Classification of sensory nerve fibres

Fibre type	Size / fibre diameter (µm)	Conduction velocity (m/s)	Characteristics	Receptor supplied
Ia	13 – 20	80 – 120	Responds to muscle length and the rate of change in muscle length.	Muscle spindle annulospiral endings.
Ib	13 – 20	80 – 120	Responds to changes in tension of a muscle.	Golgi tendon organ.
II	6 – 12	35 – 75	Stretch receptor, non-adapting.	Muscle spindle flower spray endings, all cutaneous mechanoreceptors.
III	1 – 5	3 – 35	Responds to pain.	Follicular endings, nociceptor (fast pain) and thermal receptors.
IV	0.2 – 1.5	0.5 – 2	Responds to pain.	Nociceptor (slow pain), itch, touch receptors.

(Adapted from Pickar 2002; FitzGerald, Gruener and Mtui 2012; Haines and Mihailof 2018).

Motor neurons convey action potentials away from the CNS, through cranial or spinal nerves, to effector cells in the periphery. The axons of motor neurons are myelinated and are the largest-diameter axons in the body. They are, therefore, able to propagate action potentials at high velocities, allowing signals from the CNS to travel to skeletal muscle fibres with minimal delay. Upon reaching a muscle, the axon of a motor neuron divides into many branches. The region of the muscle fibre membrane that lies directly under the terminal portion of the axon is known as the motor end plate. The junction of an axon terminal with the motor end plate is known as the neuromuscular junction. A single motor neuron innervates many muscle fibres, but each muscle fibre is controlled by a branch from only one motor neuron. The cell body of a motor neuron lies in the CNS (Crossman and Neary 2015; Tortora and Derrickson 2017). Motor neurons are called efferent neurons and are classified into three types (Table 2.2).

Table 2.2 Classification of motor nerve fibres

Fibre type	Diameter (μm)	Conduction velocity (m/s)	Function
Alpha (α) (Largest and Fastest)	12 – 20	70 – 120	Innervate extrafusal muscle fibres.
Beta (β) (Medium)	6 – 12	35 – 70	Innervates skeletal muscle and muscle spindles.
Gamma (γ) (Smallest and slowest)	3 – 6	10 - 40	Innervate intrafusal fibres of muscle spindles and controls the sensitivity of muscle spindle to stretch.

(Adapted from Leach 2004; FitzGerald, Gruener and Mtui 2012).

Interneurons are mainly located within the CNS between sensory and motor neurons. Interneurons integrate incoming sensory information from sensory neurons and then elicit a motor response by activating the appropriate motor neurons (Tortora and Derrickson 2017).

2.3.2.1 Sensory Receptors

Sensory receptors help to process changes in the internal and external environment. This information is sent to the CNS via afferent sensory nerves (Haines and Mihailof 2018). They are classified into mechanoreceptors, thermoreceptors, photoreceptors, chemoreceptors and nociceptors, based on the type of stimulus to which they are sensitive (Widmaier, Raff and Strang 2011). Those related to this studied are discussed in Table 2.3.

Table 2.3 Summary of sensory receptors

Receptor type		Location	Sensations	Adaptation rate
Mechanoreceptors	Merkel's disc	Epidermis	Touch, pressure and texture.	Slow
	Hair follicle receptors	Hair follicles.	Motion, direction.	Rapid
	Ruffini endings	Dermis of the skin, ligaments and tendons.	Skin stretch, joint position and movement.	Slow
	Pacinian corpuscles	Dermis and subcutaneous layer, submucosal tissues, joints, periosteum and some viscera	Fast vibrations, deep pressure, joint position and movement.	Rapid
	Meissener's corpuscles	Dermal papillae of hairless skin.	Fine or discriminative touch, pressure and slow vibrations.	Rapid
	Muscle spindles	Most striated skeletal muscle.	Muscle length	Slow
	Golgi tendon organs	Ligaments and tendons	Muscle tension, joint position and movement.	Slow

(Adapted from Cramer and Darby 2014; Tortora and Derrickson 2017; Haines and Mihailof 2018).

2.4 PHYSIOLOGY OF SKELETAL MUSCLE

2.4.1 Introduction

Skeletal muscle makes up the largest organ of the body, by both volume and weight, comprising of more than 40% of total body mass (Wattjes and Fischer 2013). Skeletal muscles are attached to bones by bundles of collagen fibres, known as tendons. Skeletal muscle has several functions in the body. Cael (2010) states that the primary function of skeletal muscle is to exert a pull-on the bone, creating motion. They also maintain upright posture against gravity and adjust and respond to changes in posture. Skeletal muscles protect underlying structures in areas where bones do not, such as

the abdomen. Furthermore, as skeletal muscle contracts to create movement, they also produce body heat. This is known as thermogenesis. Skeletal muscle acts individually or in co-ordination as prime movers, fixators, synergists or antagonists (Galbusera and Wilke 2018).

According to Cael (2010), skeletal muscle cells have the following characteristics that allow them to perform these functions:

- Extensibility: ability to stretch without sustaining damage. This allows muscle to lengthen when relaxed.
- Elasticity: ability to return to its original shape after stretching or shortening. As muscle tissue performs its various functions, its shape deforms. Once its work is completed, the muscle tissue can rest and resume its original shape.
- Excitability: ability to respond to stimulus by producing electrical signals. In response to an event, such as a touch or a decision to move, nerves at their junction with muscles (neuromuscular junction) release specialized chemicals called neurotransmitters. The neurotransmitters prompt the spread of an action potential that in turn triggers a series of events that lead to a muscle contraction. Without this ability to respond to the nervous system, muscles would not be able to contract and function.
- Conductivity: ability to spread or propagate an electrical signal. Once muscle tissue is stimulated by the nervous system, it must carry the electrical signal to the inner structures of the cell. Conductivity allows the action potential to be transmitted along the muscle cell, activating the tissue, and initiating a muscle contraction.
- Contractility: ability to shorten and thicken, thus producing force, in response to a stimulus. That stimulus is an action potential initiated by the nervous system. This ability to shorten is a unique feature of muscle tissue and is responsible for its force-production ability. Specialized proteins within muscle tissue interact to shorten and thicken muscles, generating force. The human body depends on this force to move.

All these characteristics are related to the microscopic structure of skeletal muscle cells.

2.4.2 Morphology

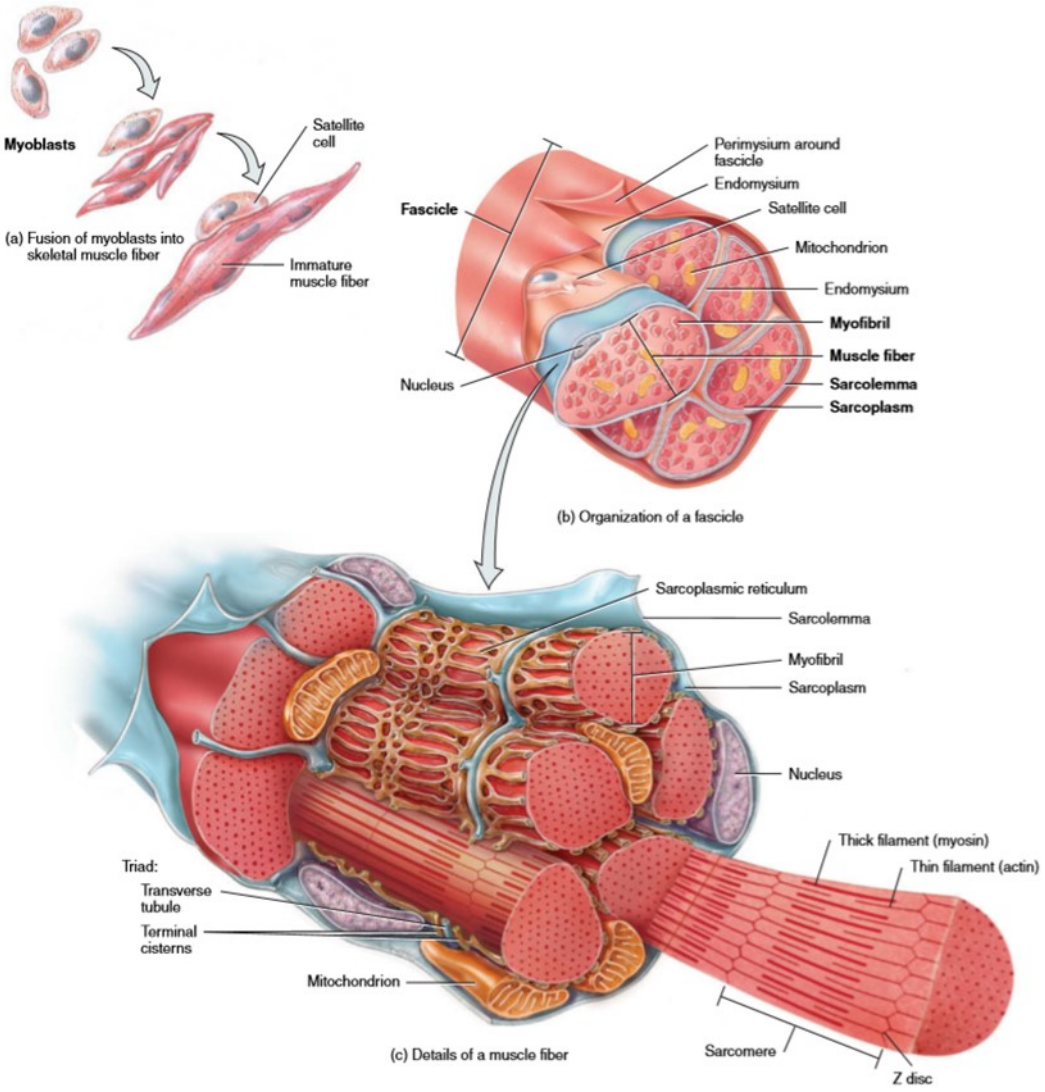

Figure 2.12 Microscopic structure of a skeletal muscle (Tortora and Derrickson 2017)

The structure of skeletal muscle is highly organized and can be studied at both a macroscopic and microscopic level. As depicted in Figure 2.12, at a microscopic level, individual muscle cells, called muscle fibres, are the smallest contractile units of the skeletal muscles. Muscle fibres develop from the fusion of precursor cells known as myoblasts. They are long, cylindrical and multinucleated cells that run parallel to each

other within a muscle. The entire muscle fibre is surrounded by the sarcolemma. The sarcolemma is the plasma membrane that is the site of conduction of action potentials. Like other cells, skeletal muscle fibres have a cytoplasm, a sarcoplasm, filled with significant amounts of glycogen, myoglobin, and mitochondria between parallel bundles of myofibrils. Myofibrils are rod-like units that attach to the sarcolemma. They are the contractile organelles of skeletal muscle and make up 80% of a single cell volume. Surrounding each myofibril is a well-developed smooth endoplasmic reticulum known as the sarcoplasmic reticulum. Numerous mitochondria and glycogen deposits are in the regions between the myofibrils. The sarcolemma has numerous invaginations, known as T (transverse) tubules that penetrate the cytoplasm to encircle each myofibril at regular intervals. Flanking the T tubules are expanded regions of the sarcoplasmic reticulum, known as terminal cisternae. These serve to store the calcium ions needed to cause a muscle contraction (Widmaier, Raff and Strang 2011; Cramer and Darby 2014).

Myofibrils consist of long proteins organized into thick and thin myofilaments. Such filaments repeat along the length of the myofibril forming the sarcomeres. A sarcomere is the functional unit of striated muscle. Sarcomeres are the units that attribute the distinctive striated appearance to skeletal muscles. They consist of interchanging dark (A bands) and light (I bands) visible in polarised light microscopy. These lighter I bands are bisected by Z bands. A sarcomere extends from Z band to Z band. The I band is made up of thin myofilaments whose ends are anchored in the Z band. The A band is composed of thick myofilaments. The A band is bisected by a lighter area known as the H band. In the middle of the H band is a narrow, dense region known as the M band. The M band represents the anchored region of the middle of the thick myofilaments and is the centre of the sarcomere. The thick and thin myofilaments partially overlap each other. Therefore, the dark portion of the A band is the region of overlap and consists of both thick and thin myofilaments. The H band is the region of the sarcomere that contains only thick myofilaments.

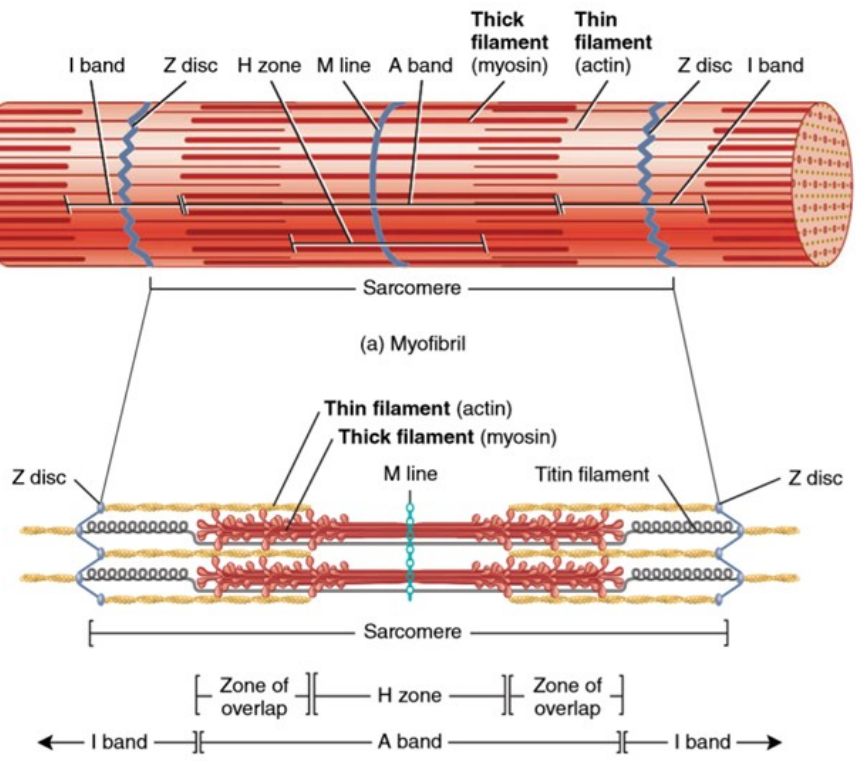

Figure 2.13 A sarcomere (Tortora and Derrickson 2017)

Thin myofilaments are composed of three proteins: actin, tropomyosin and troponin. Actin is a contractile protein. Each actin molecule has a binding site for myosin. Tropomyosin is a regulatory protein that overlaps the myosin-binding site on actin and inhibits their interaction when a muscle is in the relaxed state. Troponin is a globular protein that attaches to tropomyosin and has calcium-binding sites. Troponin, which interacts with both actin and tropomyosin, is composed of three subunits, designated by the letter I (inhibitory), T (tropomyosin) and C (calcium-binding). One molecule of troponin binds to each molecule of tropomyosin and regulates access to the myosin-binding sites on the actin molecule in contact with tropomyosin.

Thick myofilaments are composed of myosin. Each myosin molecule consists of two globular heads (containing heavy and light chains) and a long tail. Each globular head contains two binding sites, one for actin and one for adenosine triphosphate (ATP). The ATP-binding site also serves as an enzyme, ATPase, which splits ATP to generate energy for contraction. The sliding between these myofilaments to form cross-bridges

is the essential mechanism for skeletal contraction (Widmaier, Raff and Strang 2011; Cramer and Darby 2014; Galbusera and Wilke 2018).

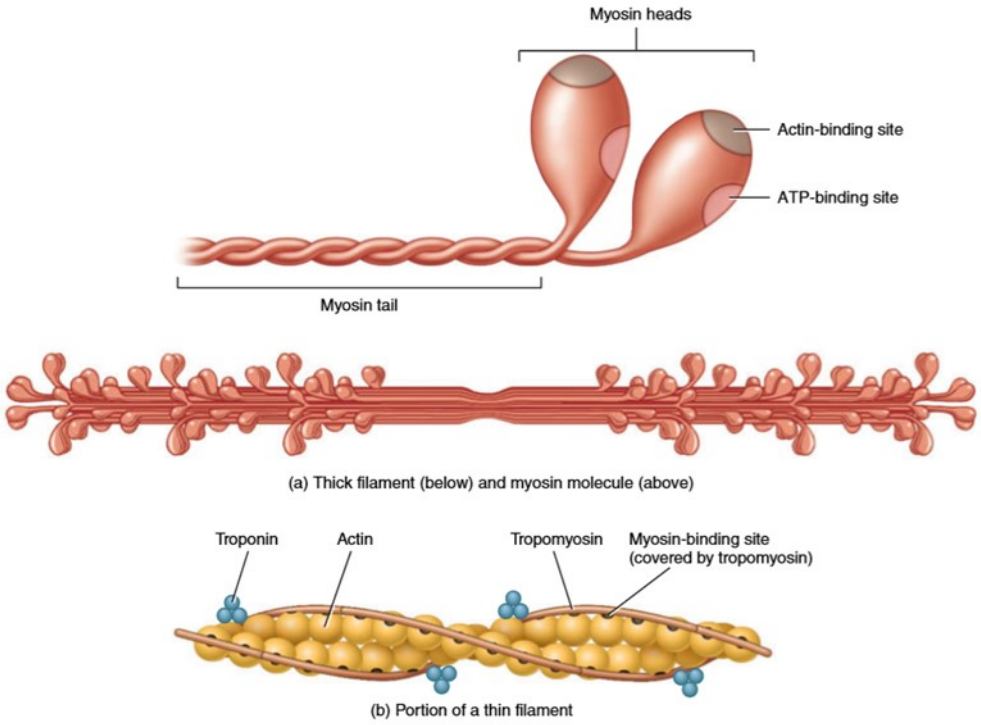

Figure 2.14 Thick and thin filaments (Tortora and Derrickson 2017)

According to Cramer and Darby (2014), there are connective tissue structures associated with skeletal muscles. The term muscle refers to a number of muscle fibres bound together by connective tissue. Connective tissue is the tissue that binds together, and provides support for, the various structures of the body. As depicted in Figure 2.15, muscle fibres are each wrapped in a sheath of relatively thin reticular connective tissue called the endomysium. The endomysium provides pathways for the passage of blood vessels and nerves. Many muscle fibres group into bundles called fascicles, which are held together and encircled by a continuous layer of collagenous connective tissue called the perimysium. Muscle fascicles are of varying sizes in diameter, ranging from a few muscle cells, to hundreds of muscle cells. This variation in fascicle diameter gives rise to a wide variation in the thickness and density of the

perimysium associated with muscle fascicles. The perimysial network blends with the epimysium at the surface of the muscle. The epimysium is a thick, dense, collagenous connective tissue that envelopes the entire muscle. All these connective tissue layers work together to help transmit force, while protecting the muscle fibres from damage during muscle contraction (Cramer and Darby 2014; Galbusera and Wilke 2018).

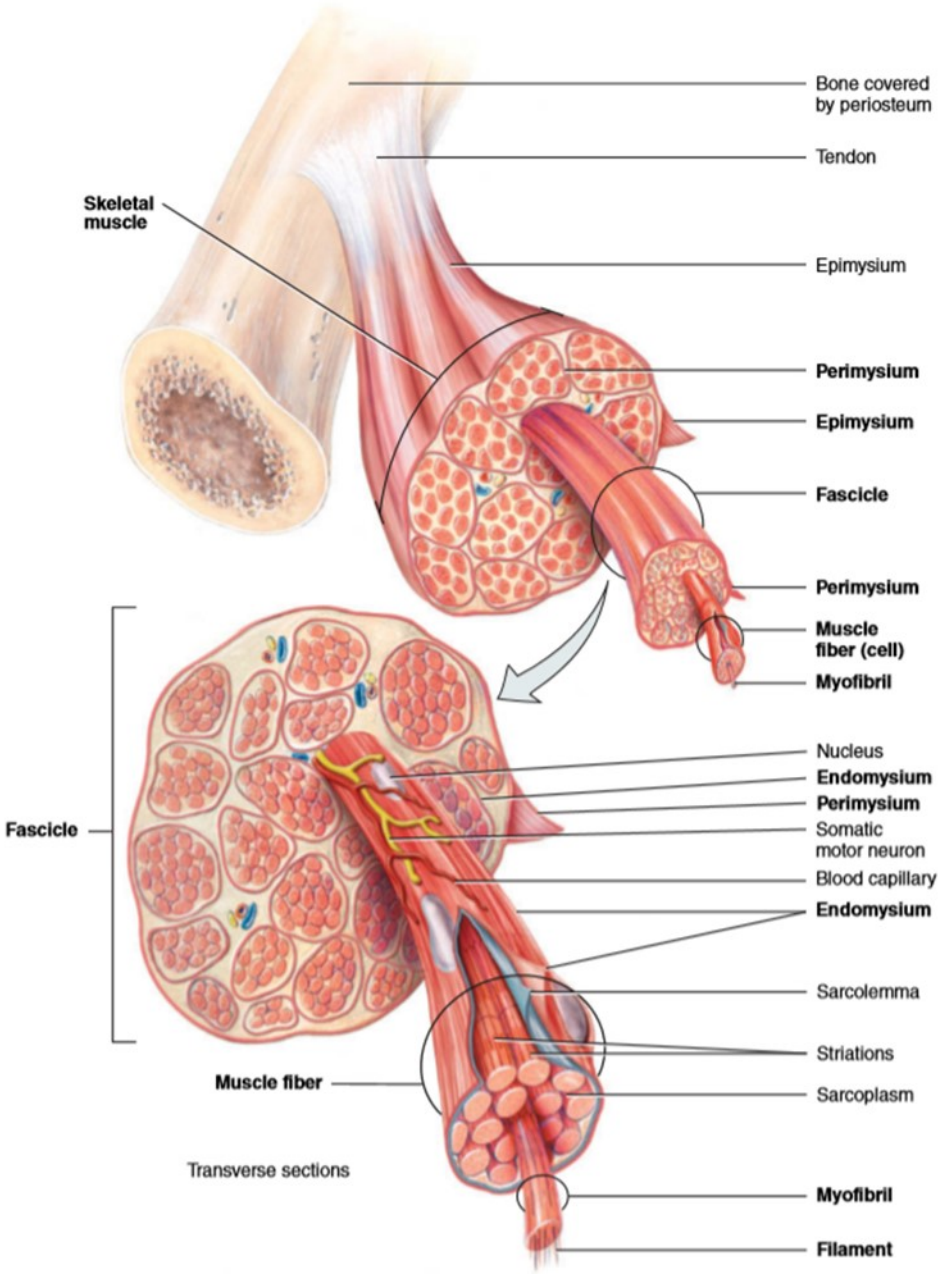

Figure 2.15 Connective tissue associated with muscle (Tortora and Derrickson 2017)

2.4.3 Motor Unit

The movement of a skeletal muscle is the direct result of the stimulation of controlling elements called motor units. An alpha motor neuron, plus the muscle fibres it innervates, is called a motor unit. A motor unit is the smallest controllable element of the CNS, representing the final pathway through which the CNS regulates voluntary muscle activity. The muscle fibres in a single motor unit are not only located in one muscle, but they are scattered throughout the muscle and are not necessarily adjacent to each other. The number of muscle fibres in a motor unit varies from one to several hundred. The number of fibres varies according to the size and function of the muscle. When an action potential occurs in a motor neuron, all the muscle fibres in its motor unit are stimulated to contract (Widmaier, Raff and Strang 2011; Moore, Dalley and Agur 2014).

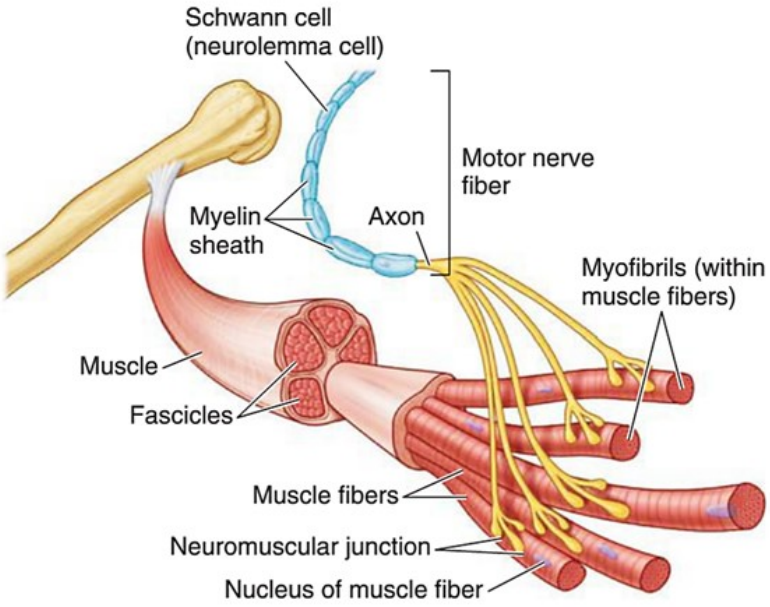

Figure 2.16 Motor unit (Tortora and Derrickson 2012)

2.4.4 Skeletal Muscle Contraction

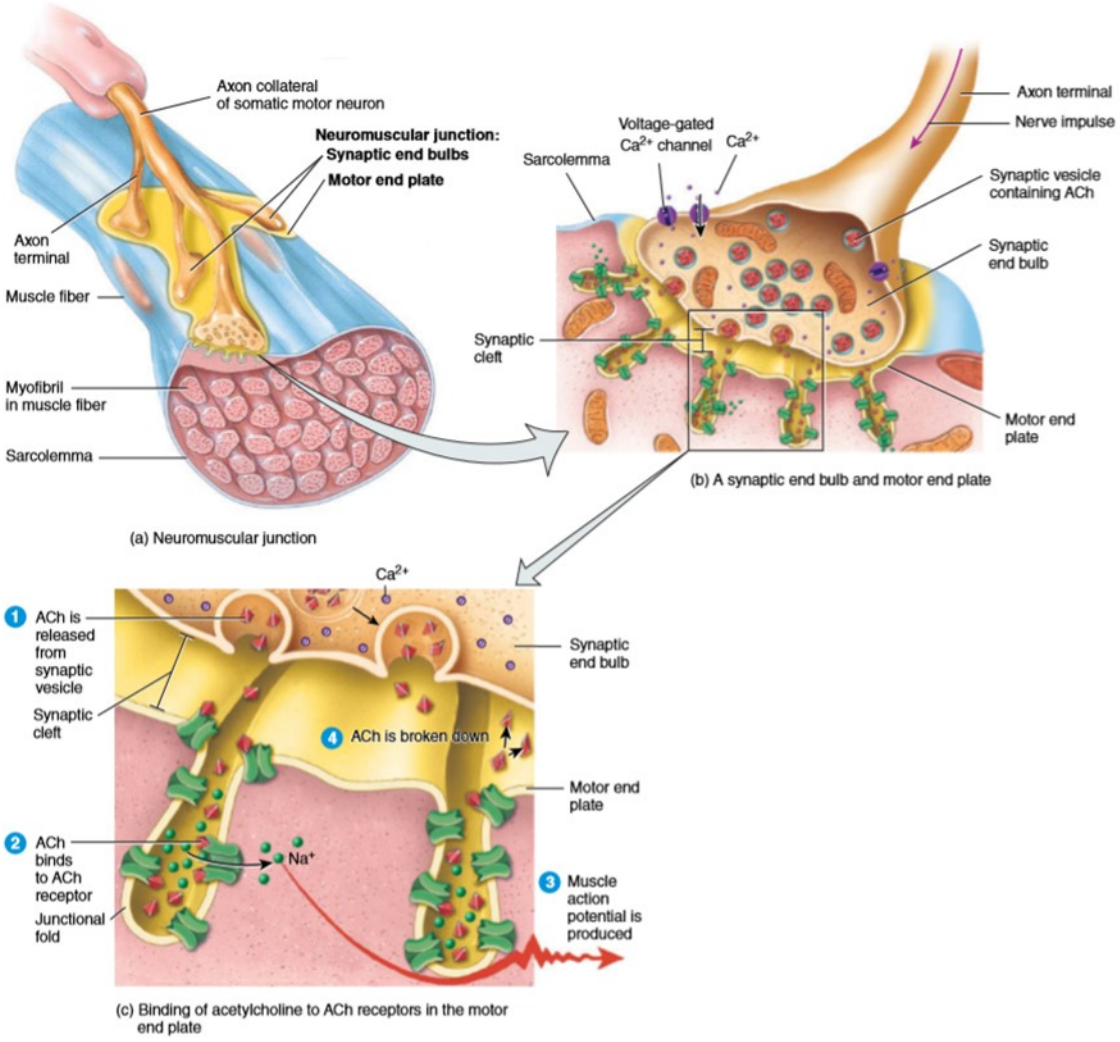

Figure 2.17 Events at the neuromuscular junction that lead to an action potential in the muscle fibre plasma membrane (Tortora and Derrickson 2017)

As shown in Figure 2.17, when an action potential in a motor neuron arrives at the axon terminal, it depolarizes the plasma membrane. This opens the voltage-sensitive calcium channels, allowing calcium in the extracellular fluid to enter the voltage-gated channels and diffuse into the axon terminal. This calcium binds to proteins that enable the membranes of Ach containing vesicles to fuse with the neuronal plasma membrane. Acetylcholine is then released into the extracellular cleft, separating the axon terminal

and the motor end plate. Acetylcholine diffuses from the axon terminal to the motor end plate, where it binds to ionotropic receptors. This binding opens ion channels in each receptor protein. Sodium and potassium ions can pass through these channels. Due to the differences in electrochemical gradients across the plasma membrane, a greater amount of sodium enters than that of potassium which moves out. This produces a local depolarization of the motor end plate known as endplate potential (EPP). The EPP depolarizes the muscle plasma membrane adjacent to the end plate membrane to its threshold potential. This initiates a muscle fibre action potential.

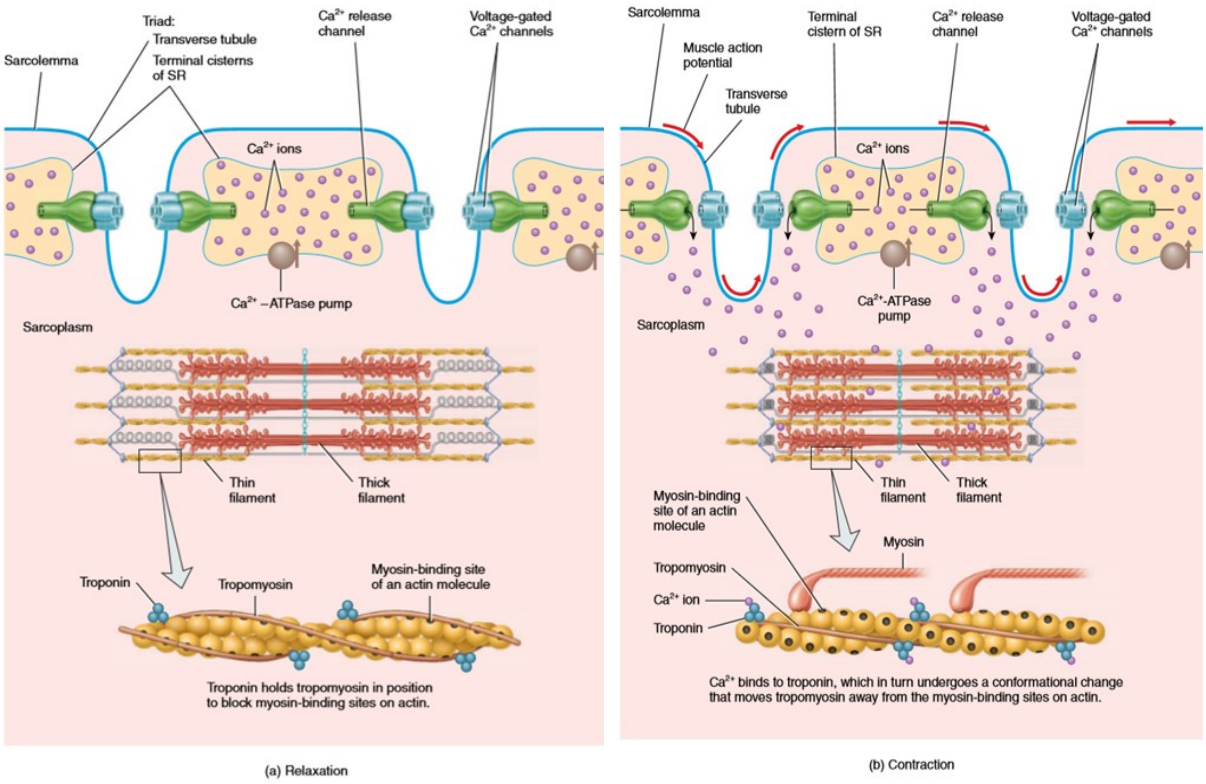

Figure 2.18 Release and uptake of calcium during contraction and relaxation of a skeletal muscle fibre (Tortora and Derrickson 2017)

As represented in Figure 2.18, the action potential is propagated in the sarcolemma. It is conducted over the surface of the fibre, and into its interior, by way of the T-tubules. This causes calcium stored in the lateral sacs of the sarcoplasmic reticulum to be

released into the cytosol. Calcium then binds to troponin, which changes the shape of tropomyosin. The inhibitory grip of tropomyosin is relaxed allowing tropomyosin to move away from the myosin-binding site on each actin molecule.

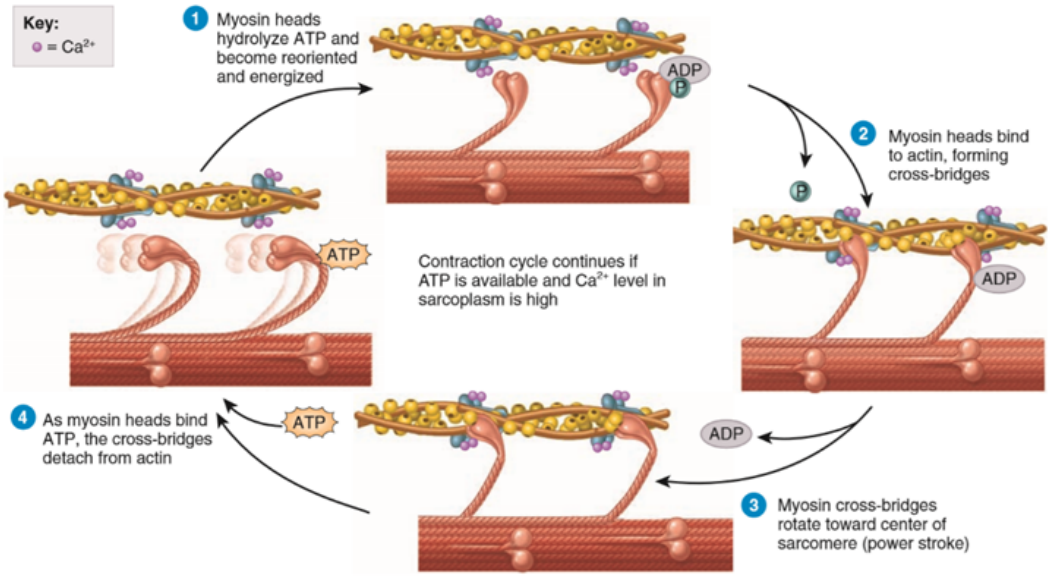

Figure 2.19 Chemical and mechanical representations of the cross-bridge cycle (Tortora and Derrickson 2012)

As depicted in Figure 2.19, the two globular heads of each myosin molecule extend from the sides of the thick filament, forming a cross-bridge. An energized myosin cross-bridge binds to a thin actin filament. Each myosin cross-bridge, attached to a thin actin filament, moves in an arc. Thus, the overlapping thick and thin filaments in each sarcomere move past each other. This swivelling motion of many cross-bridges forces the thin filaments attached to successive Z lines to move toward the centre of the sarcomere, thereby shortening the sarcomere. Hence, a reduction of the I and H bands occurs, whilst the A band remains unchanged. This is called a power stroke. One stroke of a cross-bridge produces only a very small movement of a thin filament, relative to a thick filament. However, if the muscle fibre remains activated, each cross-bridge repeats its swivelling motion many times, resulting in large displacements of the filaments. This is known as the sliding-filament mechanism of muscle contraction.

Adenosine triphosphate then binds to myosin, causing the cross-bridge to detach. The ATP that is bound to myosin is hydrolysed, thereby re-forming the energized state of myosin and returning the cross-bridge to its pre-power stroke position. The hydrolysis of ATP, and the movement of the cross-bridge, are not simultaneous events. If calcium is still present at this time, the cross-bridge can reattach to a new actin molecule in the thin filament and the cross-bridge cycle is repeated (Widmaier, Raff and Strang 2011; Cramer and Darby 2014).

The contraction ends and relaxation begins as calcium is pumped back into the sarcoplasmic reticulum. Calcium is removed from troponin, restoring the blocking action of tropomyosin. The contraction is then terminated. Due to the myofibril attachments to the sarcolemma and connective tissue, when the myofibrils contract, the entire cell shortens and pulls on the tendon (Widmaier, Raff and Strang 2011).

2.4.5 Role of Golgi Tendon Organs and Muscle Spindles

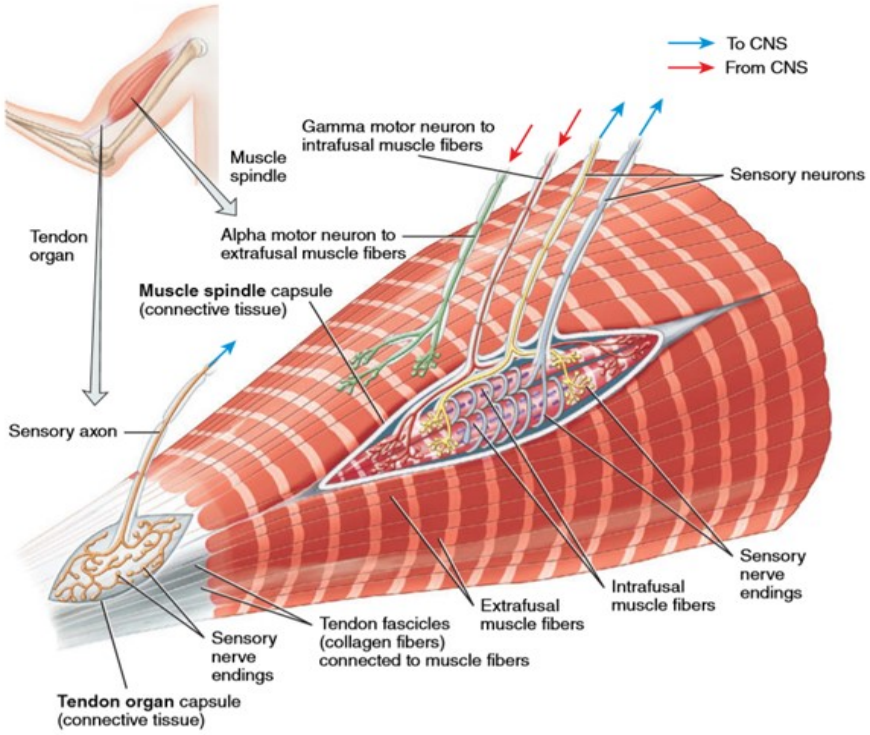

Figure 2.20 A muscle spindle and golgi tendon organ (Tortora and Derrickson 2017)

2.4.5.1 Golgi Tendon Organs

Golgi tendon organs (GTOs) are mechanoreceptors that lie within a tendon near its junction with a muscle (Figure 2.20). They protect tendons, and their associated muscles, from damage, due to excessive tension by detecting and responding to changes in muscle tension that are caused by a passive stretch or muscular contraction. Each GTO consists of a thin capsule of connective tissue that encloses tendon collagen fibres. Penetrating the capsule are one or more sensory nerve endings that entwine among and around the collagen fibres of the tendon (Cramer and Darby 2014; Crossman and Neary 2015).

When a muscle contracts or is stretched, tension in the tendon increases. This stretches and stimulates the GTO. The GTO generates nerve impulses that propagate along Ib afferent fibres to the spinal cord. After entering the spinal cord, they form excitatory synapses with interneurons. These interneurons, in turn, inhibit alpha motor neurons that innervate the muscle associated with the activated GTO. This is called the tendon reflex and operates as a feedback mechanism to control muscle tension by causing muscle relaxation before the muscle force becomes so great that tendons might be torn (Cramer and Darby 2014; Tortora and Derrickson 2017; Haines and Mihailof 2018).

The Ib sensory fibre from the GTO also synapses with an excitatory interneuron in the spinal cord. The excitatory interneuron in turn synapses with motor neurons controlling antagonistic muscles. Thus, while the tendon reflex brings about relaxation of the muscle attached to the GTO, it also triggers contraction of the antagonist. This is called reciprocal inhibition. It prevents conflict between opposing muscles and it is vital in the co-ordination of body movements. The sensory neuron also relays nerve impulses to the brain by way of sensory tracts, thus informing the brain about the state of muscle tension throughout the body (Cramer and Darby 2014; Haines and Mihailof 2018).

2.4.5.2 Muscle Spindles

Muscle spindles are sensory receptors that monitor changes in the length of skeletal muscles. Thus, they prevent overstretching of muscles and muscle fibre damage. They are stretch sensitive, fusiform-shaped proprioceptors, interspersed among skeletal

muscle fibres (extrafusal muscle fibres) and aligned parallel to them (Figure 2.20). Each spindle is encapsulated by connective tissue, within which are sensory nerve endings wrapped around three to ten intrafusal muscle fibres. The capsule anchors the spindle to the endomysium and perimysium of muscle tissue (FitzGerald, Gruener and Mtui 2012; Tortora and Derrickson 2017; Haines and Mihailof 2018).

Intrafusal muscle fibres are stretch receptors and consist of two types. One type are the nuclear chain fibres, which respond to how much a muscle is stretched. It is associated with type Ia sensory fibres, the distal ends of which are wrapped around the central region of the intrafusal muscle fibre. Thus, they are called annulospiral endings. The second type of intrafusal fibres are nuclear bag fibres, which respond to the magnitude of a stretch and the speed with which it occurs. They are associated with type II sensory fibres that form a cluster of thin, radiating branches in the central region of the intrafusal fibre. Thus, they are called secondary endings or flower-spray endings. In both types of intrafusal fibres, the nuclei occupy the central region of the fibre, making it primarily for sensory perception. The distal ends of the intrafusal muscle fibres are contractile in nature and are innervated by gamma motor neurons. They adjust the tension in a muscle spindle to the variation in the length of the muscle. (Widmaier, Raff and Strang 20011; Tortora and Derrickson 2017; Haines and Mihailof 2018).

When a muscle is stretched, the muscle spindle is elongated. The stretching of the central region of the intrafusal fibres increases the firing rate of the Ia sensory fibres. These fibres form an action potential that is conveyed to the spinal cord. In the spinal cord, the sensory neuron makes an excitatory synapse with an alpha motor neuron, thereby activating it to stimulate extrafusal muscle fibres. This results in a reflex contraction and a shortening of the muscle. This is known as the stretch reflex and helps avoid injury by preventing the overstretching of muscles (Tortora and Derrickson 2017; Haines and Mihailof 2018).

For the stretch reflex to be effective, an axon collateral (branch) from the muscle spindle sensory fibre also synapses with an inhibitory interneuron in the integrating centre. In turn, the interneuron synapses with, and inhibits, a motor neuron that normally excites the antagonistic muscles. Thus, when the stretched muscle contracts during a stretch

reflex, the antagonistic muscles that oppose the contraction relax, which is called reciprocal inhibition.

Axon collaterals of the muscle spindle sensory neuron also relay nerve impulses to the brain over specific ascending pathways. In this way, the brain receives input about the state of the stretch or contraction of skeletal muscles, enabling it to co-ordinate muscular movements. The nerve impulses that pass to the brain also allow conscious awareness that the reflex has occurred (Tortora and Derrickson 2017).

When a muscle is actively contracted against a load, an action potential is conveyed from the CNS to the alpha motor neurons to initiate muscle contraction. Simultaneously, parallel impulses are sent to the gamma neurons to cause the intrafusal fibres to contract. Therefore, when the extrafusal muscle fibres shorten, the intrafusal fibres also shorten because their gamma motor neurons are activated at the same time. As a result, the equatorial regions of the intrafusal fibres remain under nearly constant tension, because the contraction of an intrafusal fibre has the effect of stretching its central region and increasing the firing rate of Ia sensory fibres. This alpha-gamma coactivation allows the spindle to retain its ability to signal changes in muscle length as muscle contraction occurs. This circuit involving gamma motor neurons, intrafusal muscle fibres, Ia afferent fibres, alpha motor neurons and extrafusal muscle fibres is called the gamma loop. It is crucial to the maintenance of stretch reflexes and fine adjustments in muscle activity (Tortora and Derrickson 2017; Haines and Mihailof 2018).

2.5 MUSCLE ACTIVITY

Criswell (2011) states that muscle activity is a random, detached firing of groups of muscle fibres. The biomechanics of spinal movement is said to be influenced by muscle activity (Cheng *et al.* 2014). Abnormal patterns of muscle activity can result in mechanically induced pain. In addition, it may predispose the spine to an unstable state, resulting in abnormal loading, and causing neuromuscular dysfunction that results in pain. When muscle activity is increased, it is attributed to muscle hypertonicity which restricts movement (Falla, Bilenkji and Jull 2004; Kumar and Prasad 2010).

Hypertonicity is an increase in normal resting tone and is due to overactivity of motor units or changes of excitability of muscle fibres (Knutson and Owens 2003; Criswell 2011). Simons and Mense (1998) add that hypertonic muscles exhibit electromyographic activity that is not under voluntary control, and it is not dependent upon posture and may or may not be painful.

In most hypothetical models of joint dysfunction, muscle hypertonicity is presented as a potential source in the cause and maintenance of a joint dysfunction. According to Knutson and Owens (2003), these models include the facilitated segment, central sensitization, flexor or nociceptive reflex, pain-spasm-pain cycle, gamma loop, thixotropy and post contraction sensory discharge. Fryer (2003) states that the model that is cited in most osteopathic texts is Korr's (1975) neurological concept of the facilitated segment.

The facilitated segment is a neurological reflex-based theory hypothesized by Korr (1975). It is based on the premise that unguarded and unco-ordinated movements may approximate the short segmental muscles of the back. This shortening causes a slacking of the central region of the muscle spindle, creating spindle silencing. In response, the CNS would demand feedback from the spindle by increasing the gamma motor neuron discharge to the intrafusal fibres and subsequently restore the spindle afferent output discharge. This increased gamma gain increases the alpha motoneuron activity, causing excessive muscle contraction and restriction of the involved motion segment.

According to Bergmann and Peterson (2011), the concept that restricted joint movement may result from increased segmental muscle tone is supported by the knowledge that muscles not only impart movement but also impede movement. Joint movement depends on a balance between its agonist and antagonists. If this balance is lost and antagonistic muscles are unable to elongate because of involuntary hypertonicity, the joint may be restricted in its range or quality of movement (Gatterman 2005; Bergmann and Peterson 2011).

2.5.1 Surface Electromyography

Surface electromyography (sEMG) is a non-invasive, experimental technique concerned with the development, recording and analysis of action potentials associated with muscle activity (myoelectrical signals). Myoelectric signals are formed by physiological variations in the state of muscle fibre membranes. The myoelectric signal recorded at the surface electrodes is the summation of all the motor unit action potentials within the area of the detecting electrodes (Lehman 2012). The muscle activity that is recorded are relative values, relating to resting or contractile muscle states. These values are used to determine how electrically active a muscle is.

According to Bergmann and Peterson (2011), sEMG is presented as a method that can provide an objective evaluation of changes in muscle activity. Muscle dysfunction is considered to be a clinical manifestation of joint dysfunction. Thus, sEMG is said to be a method used to assess this specific characteristic of spinal dysfunction.

Several studies have been conducted on neck sEMG to determine whether dysfunctional or altered motor control patterns occur in individuals with NP. Szeto, Straker and O'Sullivan (2005) examined 21 computer administrators with neck and shoulder discomfort and 17 asymptomatic controls, whilst performing monotonous keyboard work in a standardised working environment. Head, neck, thorax and bilateral shoulder postures and movements and cervical erector spinae and upper trapezius muscle activity were recorded at the 5^{th}, 20^{th}, 35^{th}, 50^{th} and 60^{th} minute of the typing task. Office workers with neck and shoulder discomfort demonstrated increased head-neck flexion angles that were associated with significantly higher activity in the upper trapezius, which were independent of the ergonomic set-up.

The question of whether chronic NP influences muscle recruitment patterns during activities of daily living was addressed in the study by Tsang, Szeto and Lee (2014). The muscle activity of the upper trapezius, SCM and cervical and thoracic erector spinae were recorded, whilst 30 participants with NP and 30 controls performed a functional task. The task involved participants who were seated at a desk, lifting a weight from that desk to a shelf 70cm above that desk, releasing the weight onto the shelf, before picking it up again and bringing it to the desk level. This task was adopted

because it mimics actions that are commonly performed in activities of daily living. Bilateral upper trapezius and right cervical erector spinae muscle activity in both symptomatic and asymptomatic groups were highly active during the raising and release of the weight. In addition, the NP group displayed predominantly prolonged activation of the upper trapezius muscle (antagonistic muscle) during the raising phase of the task. The results infer that NP individuals are unable to fully relax their upper trapezius muscles.

In order to understand the role of muscle dysfunction in the aetiology of NP, Lascurain-Aguirrebeñ *et al.* (2018) assessed muscle activity during active neck ROM, as symptoms are said to be present during these movements. Scalene, SCM, erector spinae and upper trapezius muscle activity were recorded continuously and analysed in ten-degree increments during neck forward and lateral flexion, extension and rotation in 20 NP and 20 asymptomatic participants. The point of pain occurrence in the range of movement was also recorded. Participants with NP demonstrated increased activity of the upper trapezius and SCM, with 65% of NP participants reporting pain during at least one neck movement, most often in the last 20-40% of the range of movement.

Maroufi, Ahmadi and Khatir (2013) examined the muscle activity of the upper trapezius and cervical extensor muscles to assess the characteristics of the flexion relaxation phenomenon (FRP) in the cervical region in 22 chronic NP female participants and 21 female controls. The cervical FRP is a neck extensor myoelectric “silence” that occurs during complete cervical and lumbar flexion. The FRP was observed in 85.7% of the healthy subjects, but it was only seen in 36.3% of the NP participants. The authors state that this reduction may be due to an increased activity of the cervical erector spinae, suggesting that NP patients may have difficulties in relaxing their cervical extensor muscles.

To determine the co-contraction patterns of patients with chronic NP, Cheng *et al.* (2014), examined the SCM, splenius capitis and semispinalis capitis in 15 NP participants and 15 controls during active neck ROM. Muscle co-contraction, the simultaneous activation of agonistic and antagonistic muscles, contributes to the maintenance of spinal stability (Lee, Rogers and Granata 2006). A clarification of

muscle-contraction patterns can be helpful in understanding the control strategy of the CNS under different movement conditions and its links to neck disorders. The co-contraction ratio was defined as “the normalized integration of the antagonistic electromyography activities divided by that of the total muscle activities” (Cheng *et al.* 2014). The co-contraction ratios of the NP participants during flexion and right lateral flexion were greater than those of the healthy individuals. The results suggest that NP patients exhibit greater antagonistic muscle activity during flexion (bilateral splenius capitis and semispinalis capitis) and right lateral bending (left SCM, splenius capitis and semispinalis capitis), possibly to augment spinal stability.

When assessing the altered muscle activity associated with NP, the analysis of the upper trapezius and posterior cervical muscle activity remains congruent in the abovementioned studies. This supports the point raised by Yadav and Goyal (2015), that dysfunction of the posterior cervical and upper trapezius muscles can be a source of NP. Moreover, articular dysfunction in the cervical spine is associated with dysfunction of these muscles (Fernández de las Peñas, Cleland and Huijbregts 2011).

2.6 JOINT FIXATIONS

A joint restriction or dysfunction is proposed to be a reversible, functional disturbance of the spine (Fryer 2016). Henderson (2012) defines a joint restriction as “a biomechanical spine derangement thought to produce clinically significant effects by disturbing neurological function”. Bergmann and Peterson (2011) further explain that a joint restriction refers to a partial loss of joint movement (hypomobility) that may be in one or more directions.

It has been proposed that the presence of joint dysfunctions in asymptomatic individuals creates biomechanical and neurological consequences, which predisposes the individual to pain and other health complaints (Fryer 2016). This is due to the fact that a biomechanical alteration between vertebral segments hypothetically produces a biomechanical overload. This may alter the signalling properties of mechanically sensitive neurons in paraspinal tissues. This change in sensory input can create changes in muscle activity (Pickar 2002). Furthermore, the presence of spinal

dysfunction has an effect on central neural processing. It has been suggested that spinal dysfunction may lead to altered afferent input to the CNS. This leads to plastic changes in the way that it responds to any subsequent input. Altered afferent input from joints can lead to both the inhibition and facilitation of neural input to related muscles. Over time, altered afferent input may lead to potential maladaptive neural plastic changes in the CNS (Haavik-Taylor and Murphy 2007; Henderson 2012). Thus, a joint restriction can result in segmental muscle hypertonicity. Inversely, a hypertonic muscle can cause a joint restriction.

Fryer (2016) highlights that joint dysfunction is not synonymous with spinal pain, and palpable signs of dysfunction may be detected in both symptomatic and asymptomatic individuals. The clinical evidence of joint dysfunction consists of palpable restrictions in intersegmental ROM, characterized by abnormal or blocked joint play and end-feel of a joint; tissue texture abnormality specifically muscle hypertonicity; tenderness to palpation of the relevant joints, and asymmetry in hard or soft tissue landmarks (Haavik-Taylor and Murphy 2007; Fryer 2016; Fryer *et al.* 2017). According to Henderson (2012), intervertebral hypomobility is considered the cardinal feature of a joint dysfunction.

2.6.1 Cervical Range of Motion

Rudolfsson, Björklund and Djupsjöbacka (2012) state that decreased cervical ROM is a common finding in people with NP. Thus, the measurement of cervical ROM is essential in clinical practice to assess the functional status of patients with neck involvement and to evaluate treatment outcomes (Prushansky and Dvir 2008; Guo *et al.* 2012).

Various aspects of ROM have been investigated in the chronic and recurrent NP population. The work of Guo *et al.* (2012) focused on coupling motion and rotation ratio in the upper cervical spine of 27 participants with mechanical neck disorder (MND) and 13 controls. The ROM in the primary planes (flexion, extension, lateral flexion bilaterally and rotation bilaterally) and coupling motion (full flexion combined with rotation) were measured and the upper cervical rotation ratio was calculated. Participants with MND

demonstrated significantly reduced extension and right rotation and increased coupling motion to the right.

The question of whether the upper and lower cervical spine exhibits different ranges of motion in NP patients was addressed in a study by Rudolfsson , Björklund and Djupsjöbacka (2012). Three repetitions of active flexion and extension and axial rotation, separate for the upper and lower cervical levels, were measured for each ROM in 102 female subjects with chronic non-traumatic NP and 33 healthy female controls. Extension in the upper levels and predominantly flexion for the lower levels were reduced in participants with NP compared to the controls. The ratio between ROM for the upper and lower levels were altered in the NP group so that the lower levels contributed to a lesser extent to the total sagittal ROM compared to controls.

To determine whether kinematic measures differed between active and passive movements for participants with and without NP, Rutledge *et al.* (2012) examined the cervical lateral flexion ROM and angular velocity and coupled axial rotation of 19 NP participants and 22 controls. The results demonstrated that participants with NP had decreased active and passive lateral bending ROMs.

According to Bahat *et al.* (2014), patients presenting with NP often report difficulty in performing fast neck movements in their daily life. Thus, their study assessed cervical motion in 25 participants with chronic NP and 42 control participants during an activity that stimulates functional movement. Goal directed fast cervical movements, performed by patients with chronic NP, were characterized by lower velocity and decreased smoothness compared with asymptomatic participants. Cervical rotation proved to be faster and smoother than flexion and extension movements. Furthermore, active cervical ROM was significantly reduced in subjects with chronic NP as compared with the asymptomatic subjects.

2.7 SPINAL MANIPULATIVE THERAPY

Martel *et al.* (2011) state that around 25% of patients present to a chiropractor and complain of NP. Most chiropractors use a variety of manual therapies with the focus

being on specific adjustive techniques (Bergmann and Peterson 2011). Pagé *et al.* (2014) defines SMT as a dynamic thrust of high-velocity and low-amplitude applied at specific contact points over the spine. This is commonly referred to as an adjustment (Bergmann and Peterson 2011). It is associated with an audible pop or click- an event termed a cavitation (Evans 2002; Fryer *et al.* 2017). Cavitation is the term used to describe the formation of gaseous bubbles or cavities within the synovial fluid of a joint, as a result of a distraction, that causes a local reduction in pressure (Potter, McCarthy and Oldham 2005; Cardinale *et al.* 2015). When delivering SMT, the practitioner brings the joint to its end ROM, which is then moved slightly beyond what the patient can accomplish through voluntary activity alone. The practitioner controls the velocity, magnitude and direction of the impulse, and the skill of SMT lies in the practitioner's ability to control these three factors (Pickar and Kang 2006).

Spinal manipulative therapy is the specific and effective treatment for joint dysfunctions (Fryer 2016). It is a manual technique most commonly utilized by chiropractors, but other healthcare practitioners, including osteopaths and physiotherapists, use it as well (Pickar and Bolton 2012; Fryer *et al.* 2017). The goal in applying SMT is to restore normal motion and normalize physiology of the neuromusculoskeletal system, and potentially other physiological systems, affected by the dysfunction (Pickar and Bolton 2012). Subsequently, normal function of the cervical spine is restored (Bergmann and Peterson 2011).

Spinal manipulative therapy is one of the most utilized therapies in the management of MNDs (Martínez-Segura *et al.* 2006). Yet, the mechanisms responsible for the aetiology of clinical improvement following SMT are not yet clear (Currie *et al.* 2016). Potter, McCarthy and Oldham (2005) suggest that this may occur through biomechanical, muscular reflexogenic and/or neurophysiological mechanisms. Improving the understanding of how these mechanisms are related to clinical conditions may provide additional insight into the mechanism of SMT as a treatment, as experimental evidence of its effectiveness is lacking (Cardinale *et al.* 2015).

Spinal manipulative therapy is a mechanical intervention, that when applied to a joint fixation, produces a vertebral movement that alters the segmental biomechanics of a

joint. This decreases the strain on the paraspinal tissues and restores zygapophyseal joint mobility and end play, restoring normal ROM (Pickar 2002). Martínez-Segura *et al.* (2006) analysed the immediate (within five minutes) effect of NP, on active cervical ROM, after a single session of SMT or a control mobilization, applied to the dysfunctional level of C3, C4 or C5, in seventy mechanical NP subjects. The results demonstrated that a single cervical manipulation was more effective in reducing NP at rest and increasing ROM. The effect sizes in the manipulative group were large, suggesting a strong clinical effect. Since SMT targets specific levels to improve segmental intervertebral ROM, Branney and Breen (2012) measured the change in intervertebral range of flexion and extension after a period of manipulative treatment (twice a week for four weeks), applied to the neck of 30 NP participants and 30 controls. Measurements were taken before SMT and again at four weeks. There was a dose-related relationship between the number of manipulations received and the number of levels and directions whose intervertebral ROM increased. This provides evidence that cervical SMT has a mechanical effect at segmental levels.

Korr (1975) postulated that SMT increases joint movement by stretching the hypertonic muscles responsible for the restricted joint movement. The presence of a joint fixation causes increased gamma gain of segmental muscles of the spine to restore spindle afferent discharge. The increased gamma gain increases the alpha motoneuron activity and leads to hypertonicity (Potter, McCarthy and Oldham 2005). Korr (1975) proposed that SMT stimulates muscle spindle afferents (Group Ia and possibly II afferents) and the bombardment of afferent impulses would reduce the gain of the gamma loop and thus, restoring normal resting tone of the muscles (Pickar 2002; Gatterman 2005; Potter, McCarthy and Oldham 2005; Lehman 2012). Studies have demonstrated the phenomenon theorized by Korr (1975). DeVocht, Pickar and Wilder (2005) showed that SMT could produce an almost immediate decrease in the resting electromyographic activity of hypertonic paraspinal muscles related to an area of dysfunction. However, the utilisation of two methods for collecting electromyographic data limited the results of the study. Bicalho *et al.* (2010) then demonstrated that SMT acutely modifies paraspinal electromyographic activity during flexion-extension movements performed by forty chronic low back pain patients. Abnormal activity during the full flexion static

phase and activation during the extension phase were both reduced following SMT. However, this has yet to be demonstrated in the neck.

When SMT is applied, it activates the tissue mechanoreceptors altering the inflow of sensory impulses to the CNS which changes reflex pathways and inhibits motor neuron pools leading to a reduction of muscle hypertonicity and pain and improves the functional ability of the muscles (Pickar 2002). Herzog, Scheele and Conway (1999) examined the magnitude and extent of muscle reflex responses elicited by SMT. Ten asymptomatic males received SMT to the cervical, thoracic and lumbar spine, as well as the sacroiliac joints. Reflex responses of back and limb musculature were measured using sEMG. Reflex responses occurred within 50 to 200 milliseconds after the onset of the treatment thrust and lasted for 100 to 400 milliseconds. The authors suggested that because reflex pathways are evoked systematically during SMT, there is a distinct possibility that these responses may cause some of the clinically observed beneficial effects, such as decreased pain and hypertonicity of muscles. Dishman and Bulbulian (2000) evaluated the effect of lumbosacral spinal manipulation with thrust and spinal mobilization on the excitability of the alpha motoneuron pool in seventeen asymptomatic participants. The amplitude of the tibial nerve Hoffman reflexes was recorded before and after the interventions. The findings suggest that manual spinal therapies may lead to transient inhibition of motoneurons and it was proposed that the reduced excitability could lead to disruption of the “pain-spasm-cycle”. In both studies, the sample size was small, which, according to Faber and Fonseca (2014), increases the chance of assuming false evidence as true. Kumar (2014) further explains that findings based upon larger samples have more certainty than those based on smaller ones. Thus, the larger the sample size, the more accurate the estimate of the true population mean.

2.8 MUSCLE ENERGY TECHNIQUE

According to Pickar and Kang (2006), most chiropractic patients receive SMT as part of their chiropractic care. However, when SMT is contraindicated, other techniques are used, such as MET (Liebenson 2007). Muscle energy technique has been advocated

as a safer alternative to SMT, particularly for the upper cervical spine (Hamilton, Boswell and Fryer 2007). It has been described as a gentle form of manipulative therapy, predominantly used by osteopaths, physiotherapists and chiropractors to restore spinal ROM and to decrease pain (Lenehan, Fryer and McLaughlin 2003; Franke *et al.* 2016). Many claimed therapeutic benefits result from a single procedure of MET, making it a valuable treatment technique (Hamilton, Boswell and Fryer 2007). This includes lengthening a shortened muscle, mobilising an articulation with restricted mobility, strengthening a physiologically weakened muscle and reducing localised oedema and passive congestion (Fryer 2011; Fryer and Pearce 2013; Franke *et al.* 2016). Hamilton, Boswell and Fryer (2007) highlight that MET differs to SMT in that it is a patient-initiated contraction. Thus, the successful application of MET relies to a large extent on patient/practitioner co-operation, as the patient plays an active role in its application (Lenehan, Fryer and McLaughlin 2003). As with SMT, the mechanism responsible for the therapeutic effects of MET are unclear and the proposed mechanisms are largely speculative (Fryer 2011).

Fryer (2011) states that the underlying therapeutic action of MET may involve a variety of neurological and biomechanical mechanisms. Lenehan, Fryer and McLaughlin (2003) state that many authors of MET propose that segmental muscle contraction restricts joint motion. Muscle energy technique positions a restricted joint at the end of its limited ROM and the patient is requested to contract for five seconds against the specific counterforce applied by the practitioner. After relaxation, the restrictive barrier is often felt to yield, and the procedure is repeated several times (Lenehan, Fryer and McLaughlin 2003; Hamilton, Boswell and Fryer 2007; Fryer and Pearce 2013). During contraction of the muscle the inhibitory golgi tendon reflex is activated. This reflex produces a stretch on the golgi tendon organs and a reflex relaxation of the muscle. Parallel to SMT, Burns and Wells (2006) demonstrated that MET produces an immediate increase (i.e. one to two minutes after the intervention) in cervical spine ROM in asymptomatic individuals.

According to Fryer (2011), few studies have determined the neurophysiological effects of MET. Thus, factors other than reflex muscle relaxation seem responsible for the muscle extensibility and ROM following MET. Fryer and Pearce (2013) determined the

neurophysiological responses following MET applied to the lumbosacral joint in the lateral recumbent position bilaterally. Twelve asymptomatic volunteers aged between eighteen to fifty years underwent both control and experimental interventions with a five-minute rest period in between. Measurements were taken before and after each intervention. Transcranial magnetic stimulation (TMS) was used to produce motor evoked potentials (MEPs) and Hoffman reflexes were measured using sEMG, where electrodes were placed over the lateral head of the gastrocnemius muscle. The results suggested that MET applied to the lumbosacral joint produced a decrease in the corticospinal and spinal reflex excitability, suggesting an overall decrease in motor excitability, corresponding to SMT. The neurophysiological responses following MET in the neck, have also yet to be investigated.

An increased tolerance to stretch may also play a role in the apparent increased flexibility of muscles and decreased pain perception following MET (Ballantyne, Fryer and McLaughlin 2003; Yadav and Goyal 2015). It is highlighted by Phadke *et al.* (2016) that stretching and isometric contraction, when occurring simultaneously, stimulates the muscle and joint mechanoreceptors, producing an improvement in deep segmental muscle recruitment, motor control and joint stability. Muscle energy technique is said to produce hypoalgesia via both central and peripheral mechanisms, by activating descending neurological inhibitory pain pathways and promoting tissue fluid drainage to increase the clearance of inflammatory neuropeptides (Fryer and Pearce 2013).

2.9 SUMMARY OF THE LITERATURE

Several studies demonstrate that individuals with NP have both decreased ROM and abnormal activity of the cervical muscles, particularly the posterior cervical and upper trapezius muscles. Numerous individuals with NP seek chiropractic care. Spinal manipulative therapy is the primary treatment tool utilised by chiropractors, and MET serves as a safer alternative to SMT, particularly for the upper cervical spine (Hamilton, Boswell and Fryer 2007; Bergmann and Peterson 2011). Both these interventions are mechanical interventions applied to the spine. They influence the biomechanical function of the spine and its associated soft tissue structures, specifically modulation of

muscle activity and increased joint ROM. Studies have compared these interventions in terms of their clinical effects, showing them to have measurable clinical changes (Hurwitz *et al.* 2002; Gemmell and Miller 2006; Gross *et al.* 2010). However, there is paucity regarding the demonstration and comparison of their neurophysiological effects in the neck. Understanding these effects may assist an evidence-informed approach to technique selection (Fryer 2011). Thus, this study aims to determine the effect of SMT compared to MET on neck muscle activity and ROM in asymptomatic participants.

CHAPTER THREE: METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the design of the study, the sample population and recruitment process, the criteria for inclusion and exclusion, as well as the group allocation and randomization. It also outlines the research procedure and protocol followed and the measurement tools utilised in the study. The intervening treatments, process of statistical data analysis and ethical considerations are discussed.

3.2 STUDY DESIGN

This was a quasi-experimental study utilising a pre-test, post-test design. This study design was appropriate as it is used to compare groups and assess the impact of treatments. This design is described as two sets of cross-sectional data collection points on the same population to determine the change in the variables between two points in time. The change is measured by comparing the differences in the variables before and after the intervention. The difference between the variables is considered to be the impact of the intervention (Kumar 2014).

3.3 LOCATION OF THE STUDY

This study took place at the Durban University of Technology (DUT) Chiropractic Day Clinic (CDC), once permission had been obtained from the Clinic Director (Appendix A) and permission to access the staff and students of the university was obtained from the Research Director (Appendix B).

3.4 ETHICAL CONSIDERATIONS

This study was approved by the Institutional Research Ethics Committee (IREC) (Ethical Clearance number IREC 012/19) (Appendix C). This clinical trial was registered with the Pan African Clinical Trial Registry (PACTR201906557214661) (Appendix D).

- Participation in this study was completely voluntary and prospective participants were free to refuse participation in the study and could withdraw from the study at any point at their request.
- Participants read and signed a letter of information and informed consent (Appendix E) to participate in the study.
- Anonymity and confidentiality were ensured, as the participants' information was not included in the study. The data was coded and stored in the DUT CDC and raw electronic data was stored on a USB at DUT. After five years, the hard copies will be shredded and discarded, and the electronic data will be deleted.
- The researcher, supervisor, co-supervisor and statistician are the only individuals who had access to the data obtained from this study.
- The researcher ensured that the data was always reported on in an objective manner.
- No participant received any form of remuneration at any point.
- Non-maleficence and benefit were enforced by ensuring no harm was done to the participants as the interventions and measurement tools were safe and registered.
- Justice was accounted for as no participant was excluded from the study based on race, gender or occupation.

3.5 SAMPLING

3.5.1 Study Population

The study population consisted of 50 participants who reside in the eThekwini municipality, who were asymptomatic with respect to neck and upper quadrant pain, and met the inclusion criteria. This sample size was determined by power analysis

calculations (Appendix F) and reflects the minimum sample required for effects to be noticeable (Esterhuizen 2018). Participation in the study was voluntary and no coercion was used. Participants were free to decline or withdraw from the study at their request.

3.5.2 Recruitment

Participants were recruited by means of advertisements (Appendix G), which were placed throughout the DUT Berea and City campuses, CDC, at local Durban supermarkets and libraries, once permission had been obtained from the relevant authorities (Appendix B and H). Prospective participants were also recruited by word of mouth.

Prospective participants who responded to the advertisements contacted the researcher and underwent a patient screening with a series of questions to determine their eligibility.

Table 3.1 Patient screening

Questions asked to prospective participants	**Expected Answers**
Please may I ask you some questions?	Yes
Are you between the ages of 18 - 35?	Yes
Have you experienced neck pain in the last six weeks?	No
Are you currently experiencing neck pain?	No
Have you had any major spinal trauma or spinal surgeries?	No
Do you suffer from any chronic illnesses?	No

The patient screening was recorded by writing the answers for each person in a book. If the participant was eligible to participate in the study, an appointment was scheduled at the DUT CDC. They then read and signed a letter of information and informed consent (Appendix E).

3.5.3 Inclusion Criteria

- Participants aged 18 to 35 years. This was to exclude individuals in their fifth to seventh decade of life who are more likely to have osteoarthritis (Yochum and Rowe 2005; Neogi 2013).
- Participants with the presence of one or more cervical spine restrictions.
- Participants had to sign the letter of information and informed consent (Appendix E).

3.5.4 Exclusion Criteria

- Participants who have neck pain.
- Any participant taking medication or receiving any other form of treatment for the duration of the study.
- The presence of contra-indications to spinal manipulative therapy (Bergmann and Peterson 2011), such as:
    - Atherosclerosis of major blood vessels.
    - Vertebrobasilar insufficiency.
    - Aneurysm.
    - Tumours.
    - Fractures.
    - Late stage osteoarthritis.
    - Uncarthrosis.
    - Clotting disorders.
    - Osteopenia.
    - Space occupying lesions.
    - Diabetic neuropathy.
- The presence of contra-indications to MET (Chaitow 2006; Fernández de las Peñas, Cleland and Huijbregts 2011), including but not limited to:
    - Tissue fragility.
    - Hypermobility.
    - Myositis.

- Tumours.

- Contra-indications to surface electromyography including, but not limited to:
  - Skin irritation.
  - Open wounds, rashes, psoriasis or skin conditions of any kind in the region of the electrode placement.

3.5.5 Sample Size

This study required 50 participants, based on power analysis calculations (Appendix F) (Esterhuizen 2018). The participants who were accepted into the study were randomly allocated into two groups of 25, i.e. cervical spine manipulation (CSM) group (Group 1) and MET group (Group 2) (Esterhuizen 2018).

3.5.6 Sample Allocation

Once participants were accepted into the study, they were then randomised using the 'hat' method. A tin was filled with fifty folded slips of paper: 25 labelled "Group 1" and 25 labelled "Group 2". The tin was stirred thoroughly and, without looking, the participant drew a folded slip of paper from the tin (Thompson 2012). Therefore, each participant had an equal opportunity of being in either group. If the paper read "Group 1", then the participant fell into the CSM group. If the paper read "Group 2", then the participant fell into the MET group. The slip of paper was then discarded.

3.6 MEASUREMENT TOOLS

3.6.1 Surface Electromyography (sEMG)

The resting poster cervical and upper trapezius muscle activity was measured using surface electromyography (sEMG) (Appendix I), which is said to be a repeatable and reliable tool for measuring muscle activity (Mathur, Eng and MacIntyre 2005). Surface electromyography is a common, indirect and non-invasive tool used for the evaluation of muscle function (Oskouei, Paulin and Carman 2013). It is concerned with the development, recording and analysis of myoelectric signals (Lehman 2012). The sEMG equipment that was used to conduct this study was the Biopac-Bionomadix complete wireless research system. The system that was used also included the MP150 Data

Acquisition System, AcqKnowledge software and the Bionomadix Dual-channel Wireless EMG Transmitter and Receiver Pair.

The amplitude of the EMG signal ranges from 0-10 mV (peak to peak) or 0-1.5mV (RMS). The usable energy, which signals with energy above the electrical noise level, is limited to a frequency range of 0-500 Hz. The noise may arise from various sources, including the inherent noise in the electronic components, ambient noise, motion artefacts and inherent instability of the signal. Employing conductive electrolytes, removing dead dermis from the skin and using large surface areas for the detection surfaces can be used to reduce the noise. However, the larger detection surfaces can increase the susceptibility to crosstalk (De Luca 2002). Konrad (2005) states that cross talk involves neighbouring muscles potentially producing a significant amount of EMG that is detected by the local electrode site. The fidelity of the EMG signal is influenced by the signal to noise ratio and the distortion of the signal (De Luca 2002).

The root mean square (RMS) value, a measure of the power of the signal, is said to be the preferred method (De Luca 2002), and for this reason was collected in this study.

The static evaluation using sEMG is used to assess the resting state of the muscle. It provides an objective assessment of the resting tone, which correlates remarkably well with any hypertrophied muscle mass that is noted on palpation (Criswell 2011).

The electrodes are the devices responsible for picking up the sEMG activity, and thus their placement is essential, as this will determine the quality of the recordings (Criswell 2011). This involved placing each electrode between a motor point and the tendon insertion or between two motor points, along the longitudinal midline of the muscle. The longitudinal axis of the electrode was aligned parallel to the length of the muscle fibres. Care was taken to not place the electrode in the following areas (De Luca 2002; Criswell 2011):

- Near or on a tendon, as this will decrease the amplitude of the EMG signal, as well as make the detection susceptible to cross talk.
- The motor point, which is the point on the muscle where the introduction of minimal electrical current causes a perceptible twitch of the surface muscle fibres.

- The outside edges of the muscle, as the electrode is susceptible to detecting crosstalk signals from adjacent muscles in this region.

The resting activity of the posterior cervicals and upper trapezius were measured as they are general muscles that extend throughout the cervical spine. Electrodes were placed over the upper trapezius according to the positioning described by Criswell (2011).

Two electrodes (2 cm apart) were placed so that they ran parallel to the muscle fibres of the upper trapezius, along the ridge of the shoulder, slightly lateral to and halfway between the cervical spine at C7 and the acromion.

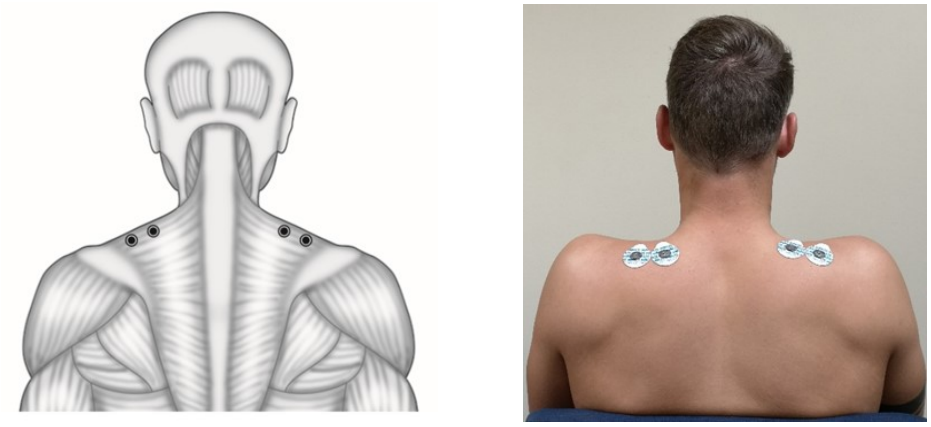

Figure 3.1 Electrode placement of the upper trapezius muscles (Criswell 2011)

Electrodes were placed over the posterior cervicals according to the positioning described by Criswell (2011). Two active electrodes (approximately 2 cm apart) were placed so that they ran parallel to the spine, approximately 2 cm from the midline, over the muscle belly at approximately C4. The hairline was to be avoided.

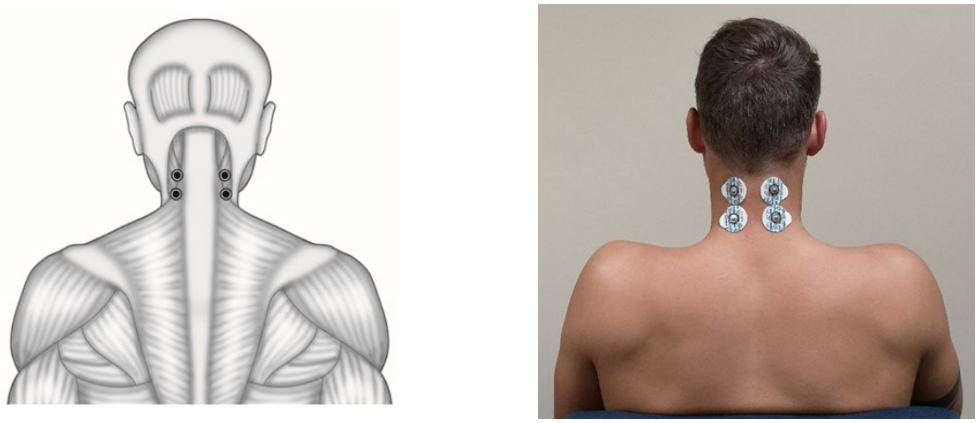

Figure 3.2 Electrode placement of the posterior cervical muscles (Criswell 2011)

3.6.2 Cervical Spine Range of Motion (CROM)

The CROM was measured using a CROM goniometer (Appendix J), which is said to have good reliability and validity (Williams *et al.* 2010*).* The CROM goniometer has three inclinometers and measures CROM in degrees. For the purpose of this study, only lateral flexion and extension was measured, as the posterior cervical and trapezius muscles control the movements of lateral flexion and the extension of the neck, respectively.

The inclinometer in the frontal plane is used for lateral flexion and the inclinometer in the sagittal plane is used for extension. These inclinometers have gravity needles (Tousignant *et al.* 2006). The participant's head and neck were placed in the neutral position. The inclinometer was read and recorded at the starting position and again at the end position (Fletcher and Brandy 2008).

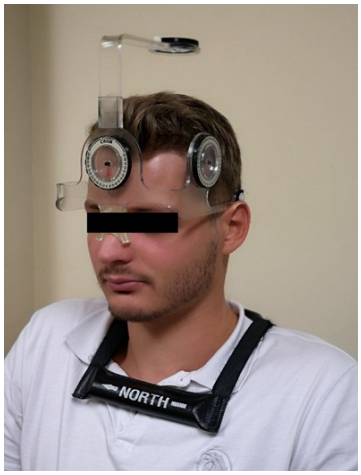

Figure 3.3 Cervical range of motion goniometer

3.7 INTERVENTIONS

3.7.1 Cervical Spine Manipulation

Cervical spine manipulation was applied to restrictions found on motion palpation. This was performed according to the technique described by Bergmann and Peterson (2011):

- Participant position:
  - C0-C1: Supine, with the head turned away from the side of dysfunction.
  - C2-C7: Supine.
- Researcher's position: Standing at the head of the table on the side of the adjustive contact, angled forty-five to ninety degrees to the participant.
- Contact point:
  - C0-C1: Hypothenar of the hand corresponding to the side of segmental contact. Contact hand is arched to cup over the participant's ear, with fingers resting on the angle of the jaw.
  - C2-C7: Ventrolateral surface of the index finger of the hand corresponding to the side of segmental contact. The thumb rests on the participant's cheek as the remaining fingers reinforce the contact.
- Segmental contact point on participant:
  - C0-C1: Occiput (posterior supramastoid groove), just posterior to the ear.
  - C1-C2: Posterior aspect of the transverse process.

    - C2-C7: Posterior articular pillar of superior vertebrae.
- Indifferent hand: Cradles the participant's head and supports the contralateral occiput.
- Vector:
    - C0-C1: Posterior to anterior, superior to inferior, and lateral to medial, for extension and lateral to medial, and superior to inferior, for lateral flexion.
    - C1-C7: Posterior to anterior, with clockwise or counter clockwise rotation to induce rotation. Posterior to anterior to induce ipsilateral extension. Medial to lateral to induce lateral flexion.
- Procedure:
    - C0-C1: For lateral flexion, induce lateral flexion toward the side of adjustive contact. For extension, laterally flex the head toward the side of contact, while rotating it away and pre-stress into extension. For rotation, rotate the patient's head away from the side of adjustive contact with slight lateral flexion toward the side of contact.
    - C1-7: For lateral flexion, laterally flex the head toward the side of dysfunction and slightly rotate the head away and thrust medioinferiorly. For extension, pre-stress the involved segment into extension and thrust anteriorly. For rotation, rotate the patient's head away, while laterally flexing it toward the side of contact and thrust in a clockwise or counter clockwise direction along the planes of the facet joint.

3.7.2 Muscle Energy Technique

This was applied to the joint restrictions, using the method outlined by DeStefano (2017). This technique was applied based on restrictions found on motion palpation.

An example of MET applied to a typical vertebra (C5 to C6), with an extension, right rotation and right-side bending restriction is:

1. The participant is supine on the table with the researcher sitting at the head.
2. The researcher's fingertips of the right index and middle finger are placed on the right articular pillar of C6 to hold the segment, so that C5 can be moved upon it.
3. The researcher's left hand controls the left side of the patient's head and neck.

4. The researcher's right fingers translate the segment anteriorly, introducing motion to the backward-bending barrier.
5. The researcher's left hand introduces side bending and rotation of the head and neck to the right by right-to-left translation, engaging the right rotation and the right-side bending barriers.
6. The participant exerts a small isometric effort against the researcher's resisting left hand into forward bending, left side bending or left rotation.
7. After a three to five second muscle effort, the participant relaxes, and the researcher increases translatory movement in an anterior and a right-to-left direction engaging the backward bending, right side bending and right rotation barriers. The process is repeated three to five times.

The technique was applied in the same manner on both right and left restrictions for C2 to C7. However, if the restriction was on the left, then the researcher would use the right hand to move the participant's cervical spine into the desired direction, whilst the left hand stabilized the vertebra inferior to the fixated segment.

For occipitoatlantal (C0 to C1), with a backward bending, left side bending and right rotation restriction:

1. The participant is supine on the table with the researcher sitting at the head.
2. The researcher's left hand controls the participant's occiput with the web of the thumb and the index finger along the soft tissues at the cervicocranial junction.
3. The researcher's right hand holds the participant's chin with the index finger in front and the middle finger below the tip of the ramus and with the right forearm in contact with the right side of the participant's head.
4. The backward bending barrier is engaged by the researcher's hands rotating the head posteriorly around a transverse axis through the external auditory meatus.
5. Left side bending is introduced through the researcher's right forearm by slight left to right translation.
6. The participant is instructed to look down at his or her feet or pull the chin toward the chest against resistance offered by the researcher's right hand for a three to five second light isometric muscle contraction.

7. After relaxation, a new backward bending, left side bending and right rotational barriers are engaged.
8. The researcher's muscle contraction is repeated three to five times with the operator relocalizing against the resisted barrier after each effort.

3.8 STUDY PROCEDURE

Once the participant had met all the requirements over a telephonic interview, an appointment at the DUT CDC was made. At the consultation, the prospective participant was given a letter of information and informed consent (Appendix E) to sign before they were allowed to take part in the study. The researcher gave a verbal explanation of the research and what was expected from the participant, at which point the participant had the opportunity to ask the researcher any questions regarding the research. The participants were informed that they were free to withdraw from the study at any time, and that this would not jeopardise any future treatments at the CDC. Prospective participants were then screened by the researcher for research compliance by completing a consultation which consisted of a case history (Appendix K), physical examination (Appendix L) and cervical spine regional examination (Appendix M), to determine if they met the study's inclusion criteria.

Participants who met the inclusion criteria were then asked to pick a folded slip of paper out of the tin to determine their group number. The slip of paper was then discarded.

Resting posterior cervical and upper trapezius electromyographic muscle activity and cervical range of motion (extension and lateral flexion) were then taken.

The CROM goniometer was attached to the participant's head and was secured with a strap. The participant was then instructed to sit in an upright position, with both feet placed firmly on the ground. The goniometer was read and recorded at the starting position for extension. The participant was then instructed to look up to the ceiling and place his or her neck as far back as possible, until limited by tightness. The goniometer was then read and recorded again at this end position. The goniometer was read and recorded at the starting position for lateral flexion. The participant was instructed to look

forward and try and bring his or her ear down to the shoulder on either side, until limited by tightness or discomfort. The measurements were recorded at these end positions (Fletcher and Brandy 2008). The measurements were recorded on the data sheet (Appendix J).

The participant's skin was prepared for electrode placement by the removal of hair with a razor, if necessary, to improve adhesion of the electrode (De Luca 2002). The skin was then cleaned will alcohol pads to remove any oils and dead skin so that the biological potentials could reach the recording electrodes easily (Criswell 2011). Electrodes were placed according to the positioning described.

Resting posterior cervical and trapezius muscle activity were measured similarly to protocols used in other studies (DeVocht, Pickar and Wilder 2005; Dunning and Rushton 2009). Prior to any collection of data, patients were seated with their head and neck in a neutral position. The participant's arms were rested with the elbows bent at ninety degrees and fingers interlocked over the abdomen to limit movement of their upper limbs. The participant was then instructed not to move any part of his or her body and to "relax as fully as possible". Baseline resting sEMG activity levels of the right and left posterior cervicals and upper trapezius were then recorded for thirty seconds before the intervention. The readings were taken for another thirty seconds after the intervention. These measurements were recorded on the data sheet (Appendix I). To avoid any changes to the results, due to differences in electrode placement between readings, the electrodes remained in the same place throughout the study (Criswell 2011), but, for the application of the intervention, the electrode leads were unclipped from the electrodes to increase participant's comfort.

Thereafter, MET or CSM was administered, as described above, according to group allocation. Resting posterior cervical and upper trapezius electromyographic muscle activity and cervical range of motion (extension and lateral flexion) recordings were then taken again.

3.9 DATA REDUCTION AND ANALYSIS

IBM SPSS version 24 was used to analyse the data. A p value <0.05 was considered as statistically significant. Normally distributed continuous variables were compared

between the two treatment groups using t-tests. Categorical variables were compared between the groups using Pearson's chi square tests or Fisher's exact tests as appropriate. All outcome variables were non-normally distributed and thus were summarized using median and inter-quartile range by group. Intra-group changes were compared pre- and post-intervention using paired Wilcoxon signed ranks tests. Median changes between pre- and post- were compared between the two treatment groups using Mann-Whitney U tests. Plots of the distributions of the values by group were graphed using Box and Whisker plots (Esterhuizen 2019).

3.10 CONCLUSION

This chapter has described the research protocol utilised in the study and explained the manner in which data was obtained and analysed. The next chapter will present the findings of the study.

CHAPTER FOUR: RESULTS

4.1 INTRODUCTION

This chapter presents the results of the study in the form of graphs and tables. Data obtained from each participant was analyzed as described in Chapter Three. The analysis included:

- Demographic data analysis comprising of age and gender.
- Background variables, comprising hand dominance, as well as the side and number of restrictions, with which participants presented.
- The distribution of resting posterior cervical and upper trapezius muscle activity and range of cervical spine extension and bilateral lateral flexion in each group.
- Intra-group changes compared pre- and post-intervention using paired Wilcoxon signed ranks tests.
- Median changes between pre- and post-intervention compared between the two intervention groups using Mann-Whitney U tests.

This study was based on the following hypotheses:

- Null hypothesis

  In the absence of consistent findings from the available literature comparing the effect of CSM to MET on neck muscle activity and ROM in asymptomatic participants, the following null hypothesis was set prior to the onset of the work: There will be no differences between the CSM and MET treatment groups in terms of surface electromyographic activity and ROM.

- Alternate hypothesis

  The following one directional hypothesis was set with respect to the null hypothesis: There will be a statistically significant difference between the CSM and MET treatment groups in terms of surface electromyographic activity and cervical ROM.

4.2 DEMOGRAPHIC AND BACKGROUND VARIABLES

4.2.1 Age

The sample consisted of 50 participants between the ages of 18 to 35 years, who responded to the advertisements and who met the inclusion criteria. Table 4.1 displays the mean age of the sample within the individual groups.

Table 4.1 Mean age per group

Group	N	Mean	Std. Deviation	Std. Error Mean	*p* Value
SMT	25	23.56	2.888	.578	0.963
MET	25	23.60	3.109	.622	

Participants in the SMT group had an average age of 23.56 years, whereas participants in the MET group had an average age of 23.60 years. There were no significant differences between the two group's mean ages (p = 0.963) (Table 4.1).

4.2.2 Gender

This study included participants of both genders. Table 4.2 shows the number and percentage of males and females comprising the total population sample. The number and percentage of males and females within each group are also shown.

Table 4.2 Gender distribution

Group	MALE		FEMALE	
	Count	Column N%	Count	Column N%
SMT	11	44.0	14	56.0
MET	12	48.0	13	52.0
Total	23	46.0	27	54.0
***p* Value**	0.777			

The gender distribution did not differ significantly between the two groups (p = 0.777). The female population comprised 54.0% of the total population sample, whilst the male population was 46.0%.

4.2.3 Background Variables

Hand dominance, as well as the side and number of restrictions with which the participants presented, were recorded. Table 4.3 summarizes the number and percentage of these variables in each group.

Table 4.3 Background variables

Group	HAND DOMINANCE			SIDE OF THE JOINT RESTRICTION			NUMBER OF JOINT RESTRICTIONS		
	Right	Left	Ambidextrous	Right	Left	Both	1	2	3
SMT	23 (92.0%)	1 (4.0%)	1 (4.0%)	8 (32.0%)	1 (4.0%)	16 (64.0%)	3 (12.0%)	16 (64.0%)	6 (24.0%)
MET	23 (92.0%)	0 (0.0%)	2 (8.0%)	11 (44.0%)	4 16.0%)	10 (40.0%)	7 (28.0%)	17 (68.0%)	1 (4.0%)
Total	46 (92.0%)	1 (2.0%)	3 (6.0%)	19 (38.0%)	5 (10.0%)	26 (52.0%)	10 (20.0%)	33 (66.0%)	7 (14.0%)
p Value	*1.000			*0.167			*0.080		

*Fisher's exact 2-sided test.

Table 4.3 depicts that most participants were right hand dominant (92%) and presented with two restrictions (66%), one on either side of the cervical spine (52%). Thus, for most participants, either CSM or MET was applied to two cervical joint restrictions. Hand dominance ($p = 1.000$), the side of the joint restriction ($p = 0.167$) and the number of joint restrictions ($p = 0.080$) did not differ significantly between the two groups.

Tables 4.2 and 4.3 show that none of the demographic or background variables differed significantly between the two groups.

4.3 ANALYSIS OF THE PRIMARY DATA

To characterize the nature (increase/decrease) of any change in outcomes produced by each intervention, the pre-intervention reading was subtracted from the post-intervention reading. If the pre-post intervention change was calculated as a positive value, then it demonstrated an increase in that respective outcome following the intervention. If the difference was calculated as a negative value, then it demonstrated a decrease in that respective outcome, compared to the pre-intervention reading.

The Box and Whisker graphs show the distribution of the values pre- and post-interventions, by group. The dark line in the middle of the box is the median value, the bottom of the box is the 25^{th} percentile and the top of the box is the 75^{th} percentile. The whiskers are the range of values. Circles represent both outliers and extreme points.

4.3.1 Objective One

To determine the effects of CSM on the surface electromyographic muscle activity of the posterior cervical and upper trapezius muscles and CROM (extension and lateral flexion).

4.3.1.1 Surface Electromyographic Muscle Activity

Table 4.4 summarizes the distribution of surface electromyographic muscle activity values in the SMT group using median and inter-quartile ranges.

Table 4.4: Distribution of surface electromyography values in the SMT group

	Right posterior cervicals			Left posterior cervicals			Right upper trapezius			Left upper trapezius		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Median	.0099	.0097	.0000	.0062	.0056	-.0001	.0048	.0044	-.0001	.0100	.0100	.0000
Percentile 25	.0096	.0095	-.0001	.0052	.0050	-.0011	.0042	.0037	-.0008	.0097	.0097	-.0002
Percentile 75	.0104	.0103	.0000	.0074	.0066	.0004	.0054	.0048	.0002	.0107	.0106	.0001

Table 4.4 demonstrates that sEMG values in the SMT group were all distributed around 0, with most post-SMT values being lower than the pre-SMT values. The distribution of muscle activity changes pre- to post-SMT are mostly negative values, demonstrating that mostly reductions in muscle activity occurred following SMT. However, this was only significant for the right posterior cervical muscles (p = 0.012; paired Wilcoxon signed ranged tests).

Figure 4.1 illustrates the values presented in Table 4.4 graphically.

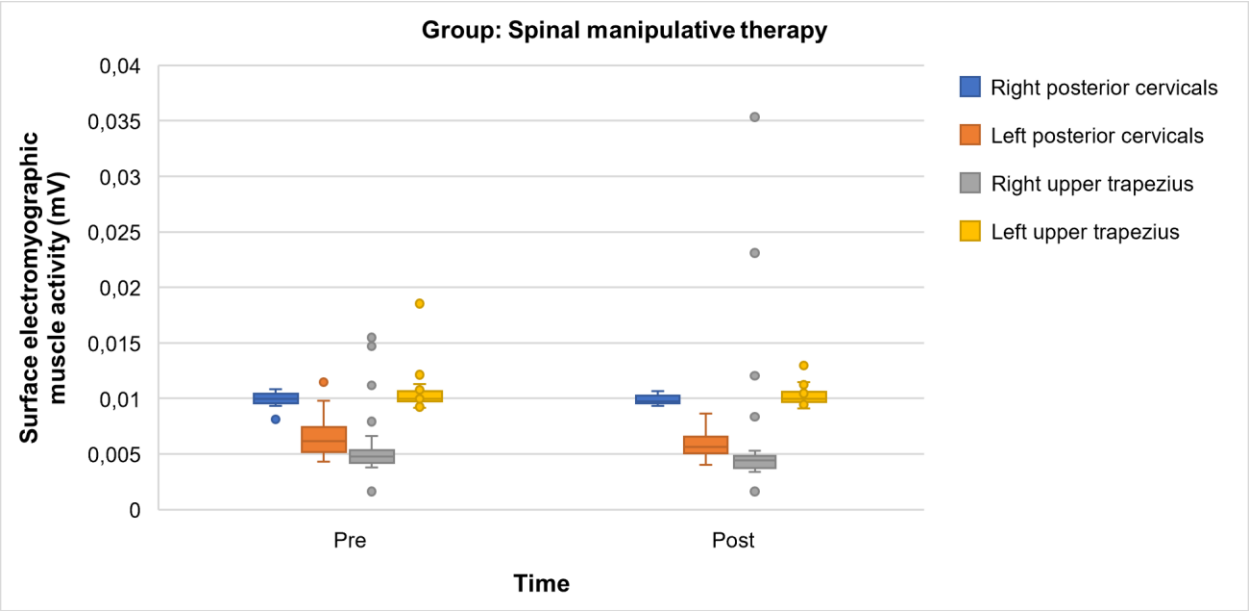

Figure 4.1 Distribution of surface electromyography values in the SMT group

As displayed in Figure 4.1, the range of values pre-SMT are larger than those post-SMT. Median sEMG values were lower post-SMT, indicating that mostly reductions in muscle activity occurred in the SMT group. This was only significant for the right posterior cervical muscles (p = 0.012).

4.3.1.2 Cervical Range Of Motion

Table 4.5 summarizes the distribution of CROM values in the SMT group, using median and inter-quartile ranges.

Table 4.5 Distribution of cervical range of motion values in the SMT group

	Extension			Right lateral flexion			Left lateral flexion		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Median	80.0	80.0	2.0	50.0	52.0	2.0	52.0	54.0	2.0
Percentile 25	62.0	62.0	.0	44.0	50.0	2.0	48.0	50.0	2.0
Percentile 75	90.0	90.0	6.0	50.0	58.0	6.0	56.0	60.0	6.0

As depicted in Table 4.5, CROM values in the SMT group were all distributed above 0, with most post-SMT values being greater than the pre-SMT values. The distribution of CROM changes pre- to post-SMT are all positive values, demonstrating that improvements in CROM occurred following SMT. This was significant for extension, as well as right and left lateral flexion ($p < 0.001$; paired Wilcoxon signed rank tests).

Figure 4.2 provides a graphic representation of the values presented in Table 4.5.

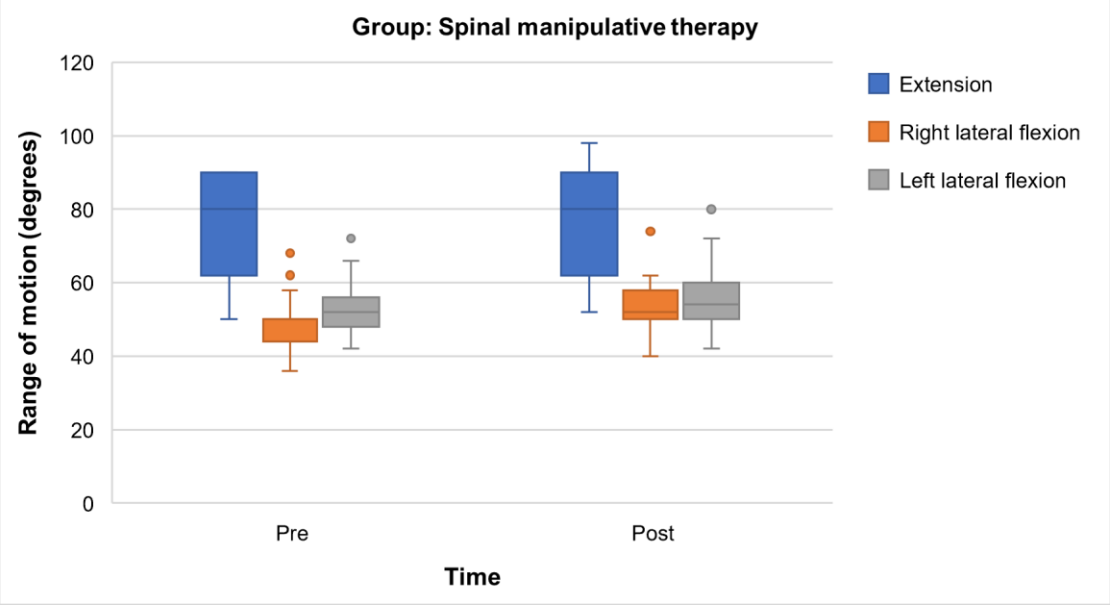

Figure 4.2 Distribution of CROM values in the SMT group

Figure 4.2 illustrates that the range of values post-SMT are larger than those pre-SMT. Median sEMG values were higher post-SMT, indicating that improvement in CROM occurred in the SMT group. This was significant for extension, right and left lateral flexion ($p < 0.001$; paired Wilcoxon signed rank tests).

4.3.2 Objective Two

To determine the effects of MET on the surface electromyographic muscle activity of the posterior cervical and upper trapezius muscles and CROM (extension and lateral flexion).

4.3.2.1 Surface Electromyographic Muscle Activity

The distribution of surface electromyographic muscle activity values in the MET group are summarized using median and inter-quartile ranges in Table 4.6.

Table 4.6 Distribution of surface electromyography values in the MET group

	Right posterior cervicals			Left posterior cervicals			Right upper trapezius			Left upper trapezius		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Median	.0100	.0101	-.0001	.0089	.0058	-.0002	.0045	.0045	.0000	.0103	.0102	-.0002
Percentile 25	.0097	.0096	-.0001	.0050	.0047	-.0006	.0041	.0041	-.0001	.0097	.0097	-.0004
Percentile 75	.0103	.0105	.0000	.0068	.0070	.0007	.0049	.0047	.0003	.0120	.0111	.0001

Table 4.6 shows that the distribution of surface electromyographic muscle activity values in the MET group were all around 0. The distribution of changes pre- to post-MET were calculated as mostly negative values. This indicates that mostly reductions in muscle activity occurred following MET. However, this was not significant for the right ($p = .157$) or left posterior cervical muscles ($p = .925$), nor the right ($p = .533$) or left upper trapezius muscles ($p = .174$).

Figure 4.3 illustrates the values presented in Table 4.6 graphically.

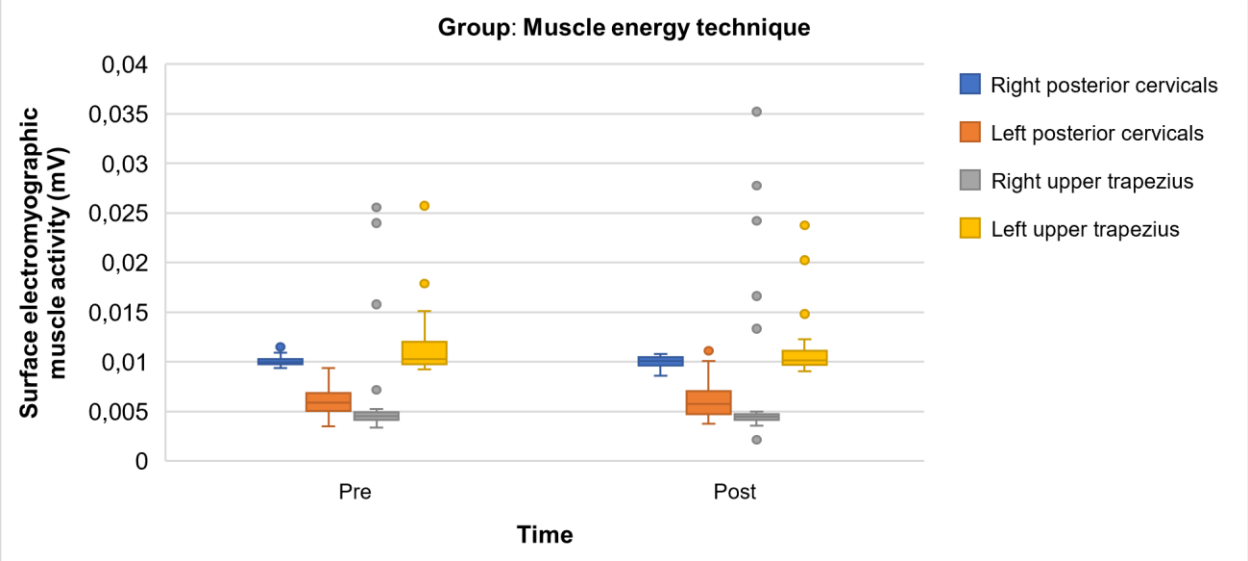

Figure 4.3 Distribution of surface electromyography values in the MET group

Figure 4.3 demonstrates that the range of muscle activity values post-MET are smaller than those pre-MET. Median sEMG values were lower post-MET, indicating that mostly reductions in muscle activity occurred in the MET group. This was not significant for any of the surface electromyographic variables as the *p* value was greater than 0.05.

4.3.2.2 Cervical Range of Motion

Table 4.7 presents the distribution of CROM values in the MET group summarized using median and inter-quartile ranges.

Table 4.7 Distribution of cervical range of motion values in the MET group

	Extension			Right lateral flexion			Left lateral flexion		
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
Valid N	25	25	25	25	25	25	25	25	25
Median	80.0	84.0	2.0	50.0	56.0	2.0	60.0	60.0	2.0
Percentile 25	70.0	80.0	.0	40.0	50.0	.0	50.0	52.0	.0
Percentile 75	82.0	90.0	8.0	60.0	60.0	10.0	62.0	64.0	4.0

As shown in Table 4.7, the distribution of changes pre- to post-MET were all calculated as positive values, indicating an improvement in CROM following MET. This was significant for extension, right and left lateral flexion ($p < 0.001$; paired Wilcoxon signed rank tests).

Figure 4.4 presents the values displayed in Table 4.7 graphically.

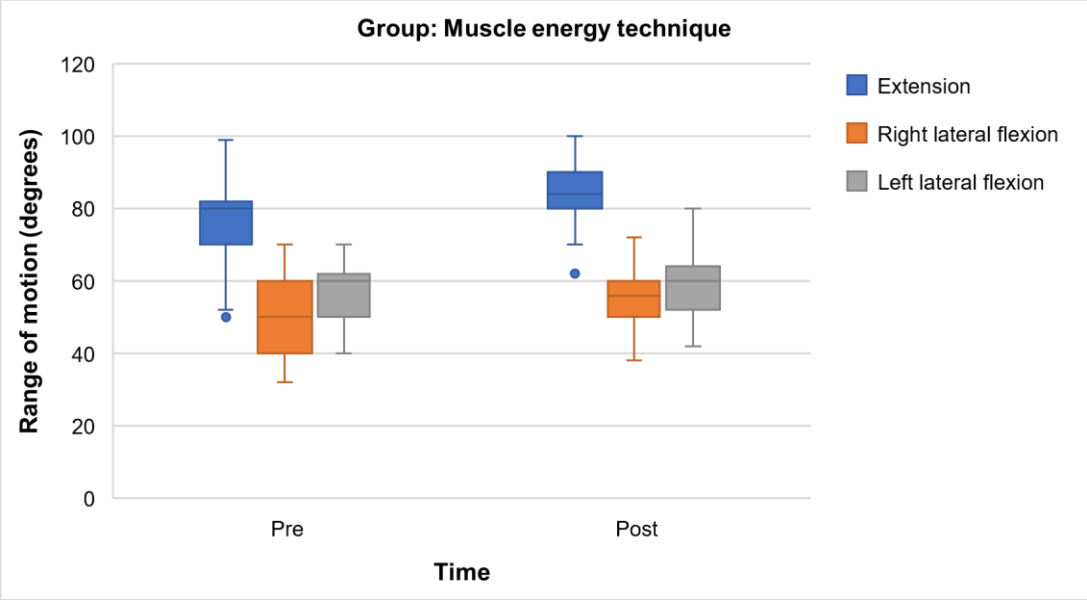

Figure 4.4 Distribution of CROM values in the MET group

Figure 4.4 illustrates that the range of values post-MET are larger than those pre-MET. Median CROM values were higher post-MET, indicating that improvement in CROM occurred in the MET group. This was significant for extension, right and left lateral flexion ($p < 0.001$; paired Wilcoxon signed rank tests).

4.3.3 Objective Three

To compare and correlate the data (surface electromyographic muscle activity and CROM) between the two intervention groups, i.e. to assess whether changes from baseline in outcomes are correlated within treatment groups and between treatment groups.

4.3.3.1 Intra-Group Analysis

Table 4.8 presents intra-group changes compared pre- and post-intervention using paired Wilcoxon signed ranks tests.

Table 4.8 Intra-group analysis of changes in values between pre and post treatment

		TEST STATISTICS [a]						
		Surface electromyographic muscle activity				Cervical range of motion		
Group		rpc/post - rpc/pre	lpc/post - lpc/pre	rut/post – rut/pre	lut/post - lut/pre	ext/post - ext/pre	rlf/post - rlf/pre	llf/post - llf/pre
SMT	Z	-2.518[b]	-1.413[b]	-1.143[b]	-.552[b]	-3.752[c]	-3.861[c]	-3.877[c]
	Asymp. Sig. (2-tailed)	.012	.158	.253	.581	<0.001	<0.001	<0.001
MET	Z	-1.415[b]	-.094[b]	-.624[c]	-1.359[b]	-3.736[c]	-3.550[c]	-3.475[c]
	Asymp. Sig. (2-tailed)	.157	.925	.533	.174	<0.001	<0.001	<0.001
a. Wilcoxon Signed Ranks Test								
b. Based on positive ranks								
c. Based on negative ranks								

rpc = right posterior cervical muscles; lpc = left posterior cervical muscles; rut = right upper trapezius muscles; ext = extension; rlf = right lateral flexion; llf = left lateral flexion.

Table 4.8 reveals that there were significant intra-group differences from pre- to post-intervention for the right posterior cervical muscles in the SMT group (p = 0.012). In addition, there were significant changes from pre- to post-SMT for extension, right lateral flexion and left lateral flexion (p < 0.001). No significant changes were experienced for muscle activity in the MET group, but, there were significant changes from pre- to post-MET for extension, right lateral flexion and left lateral flexion (p < 0.001). Therefore, both treatments were equally effective for the ROM outcomes.

4.3.3.2 Inter-Group Analysis

Table 4.9 presents the median changes compared between groups using Mann-Whitney U tests.

Table 4.9 Inter-group analysis

HYPOTHESIS TEST SUMMARY				
	Null Hypothesis	**Test**	**Sig.**	**Decision**
1	The distribution of rpc/change is the same across categories of group.	Independent Samples Mann-Whitney U Test	.371	Retain the null hypothesis.
2	The distribution of lpc/change is the same across categories of group.	Independent Samples Mann-Whitney U Test	.383	Retain the null hypothesis.
3	The distribution of rut/change is the same across categories of group.	Independent Samples Mann-Whitney U Test	.101	Retain the null hypothesis.
4	The distribution of lut/change is the same across categories of group.	Independent Samples Mann-Whitney U Test	.290	Retain the null hypothesis.
5	The distribution of ext/change is the same across categories of group.	Independent Samples Mann-Whitney U Test	.744	Retain the null hypothesis.
6	The distribution of rlf/change is the same across categories of group.	Independent Samples Mann-Whitney U Test	.936	Retain the null hypothesis.
7	The distribution of rllf/change is the same across categories of group.	Independent Samples Mann-Whitney U Test	.102	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

rpc = right posterior cervical muscles; lut = left upper trapezius muscles; ext = extension; rlf = right lateral flexion; llf = left lateral flexion.

As seen in Table 4.9, there were no significant changes between the SMT and MET group for any of the muscle activity or ROM outcomes. This indicates that the distribution of outcomes was the same in both groups. Thus, the null hypothesis was retained.

Figure 4.5 illustrates the changes in electromyographic muscle activity per muscle between the SMT and MET group.

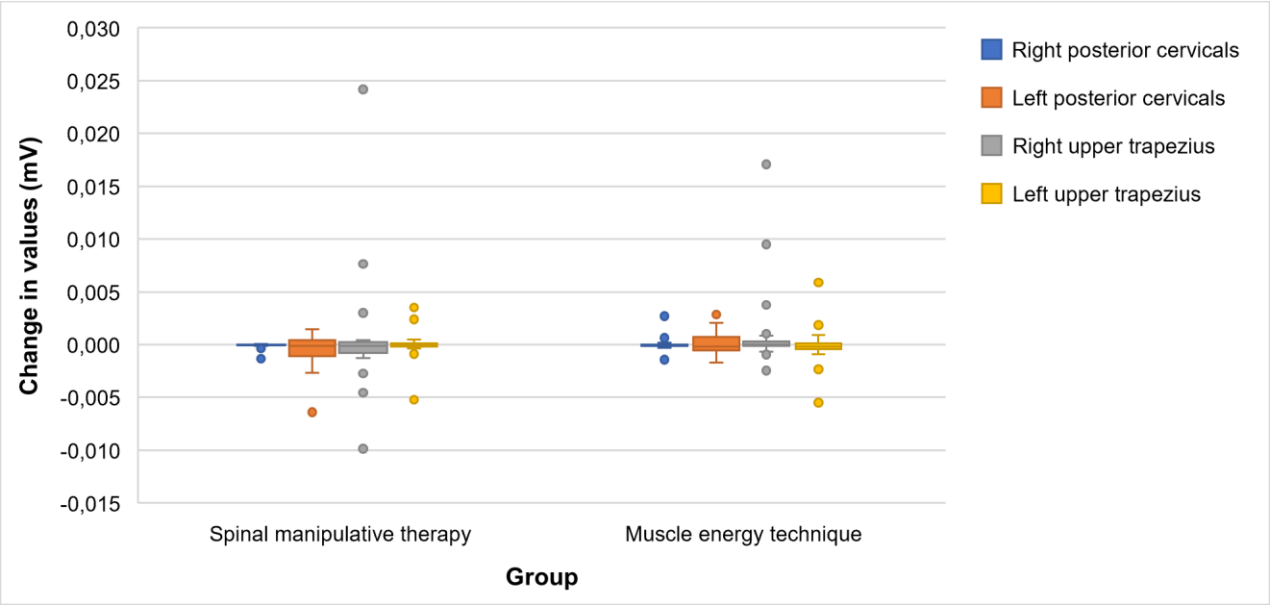

Figure 4.5 Inter-group changes in resting surface electromyographic muscle activity

Figure 4.5 reveals that changes in the EMG readings were all distributed around 0 (some above and some below) indicating that the average change was around 0. This was similar in both groups. There was also no significant difference in the change between pre- and post- for any of the EMG variables [right posterior cervicals $p = 0.371$; left posterior cervials $p = 0.383$; right upper trapezius $p = 0.101$; left upper trapezius $p = 0.290$ (Mann-Whitney U tests)].

Figure 4.6 shows the changes in cervical spine extension and bilateral lateral flexion between groups.

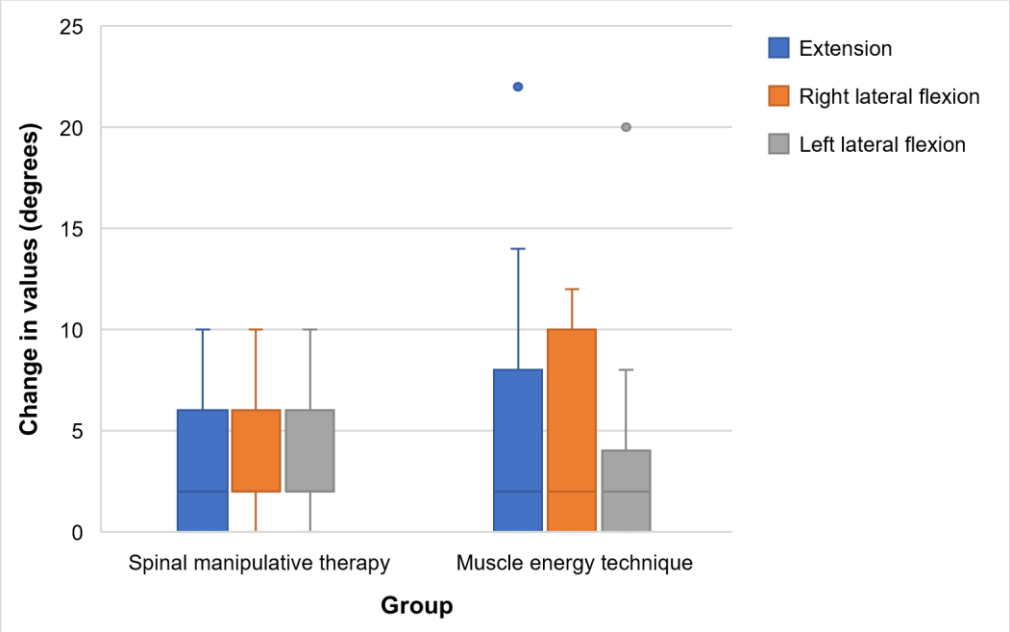

Figure 4.6 Inter-group changes in cervical range of motion

Figure 4.6 illustrates that for the CROM, the changes were all distributed above 0 (improvement). This was similar in both groups. There was also no significant difference in the change between pre- and post- for any of the ROM variables [Extension $p = 0.744$; right lateral flexion $p = 0.936$; left lateral flexion $p = 0.102$ (Mann-Whitney U Tests)].

4.4 CONCLUSION

While for some of the outcomes, ROM especially, there was evidence of a general improvement after treatment in both groups, there was no evidence of a difference in treatment effect between the two treatments in this study on EMG outcomes or ROM outcomes. Therefore, the null hypothesis is retained.

CHAPTER FIVE: DISCUSSION

5.1 INTRODUCTION

This chapter will discuss the results presented in Chapter Four in the context of current literature. The statistical and clinical significance of the sEMG and CROM data obtained from the intra-group and inter-group analysis will be discussed in relation to possible theories. References will be made to relevant sections in Chapter Four, in addition to the studies discussed in Chapter Two.

5.2 DEMOGRAPHICS AND BACKGROUND VARIABLES

5.2.1 Age

Age was an inclusion criterion in this study and was limited to individuals between the ages of 18 to 35 years. Participants in this age range were chosen in order to limit individuals in their fifth to seventh decade of life, who are more likely to have osteoarthritis (Yochum and Rowe 2005; Neogi 2013). Additionally, due to the development of degenerative changes, age influences the majority of primary and coupled movements producing a decline in CROM in all primary planes. Thus, CROM decreases with increasing age (Malmström *et al.* 2006; Simpson *et al.* 2008; Lansade *et al.* 2009; Park *et al.* 2014). Age does not appear to influence sEMG levels at rest (Criswell 2011). Thus, this study controlled for age to limit the risk of osteoarthritis and poor CROM data.

Table 4.1 indicates that the mean age was 23.60 years in the SMT group and 23.56 years in the MET group. This indicates that the SMT and MET group were comparable due to their almost identical mean age values ($p = 0.963$). This is comparable to studies conducted by Burns and Wells (2006) and Fryer and Pearce (2013), where the mean ages were 26.81 years and 25.9 years, respectively. Conversely, most participants were students, which would account for the mean age values being significantly

younger than those of previous studies (Dishman and Bulbulian 2000; Martínez-Segura *et al.* 2006; Bicalho *et al.* 2010; Branney and Breen 2012).

5.2.2 Gender

Participants of both genders were included in the study, as gender does not appear to be an important factor when assessing muscle activity and CROM. Criswell (2011) states that for resting sEMG recordings, gender differences show too much random variation to provide a meaningful distinction between genders. Additionally, studies conducted on the effect of gender on CROM revealed that gender does not appear to influence CROM (Malmström *et al.* 2006; Simpson *et al.* 2008; Lansade *et al.* 2009).

There were slightly more female participants than males. The total number of male participants was 23 (46%) and females was 27 (54%). Nevertheless, this difference was not significant (p = 0.777), making the groups comparable. The inclusion of both genders, with a greater percentage of female participants, is in accordance with previous studies (Burns and Wells 2006; Martínez-Segura *et al.* 2006; Bicalho *et al.* 2010; Branney and Breen 2012; Fryer and Pearce 2013) However, this is at variance with Dishman and Bulbulian (2000), wherein there was a larger number of male participants and it is in contrast to Herzog, Scheele and Conway (1999), where the study consisted of only male participants.

5.2.3 Background Variables

The majority of the participants were right hand dominant (92%) and presented with two joint restrictions (66%) that were bilateral in nature (52%). Nevertheless, Table 4.3 shows that hand dominance (p = 1.000), the side of the joint restriction (p = 0.167) and the number of joint restrictions (p = 0.080) did not differ significantly between the two groups.

Branny and Breen (2012) demonstrated the presence of a dose-related relationship between the number of manipulations received and the number of levels and directions whose intervertebral CROM increased. Moreover, Martínez-Segura *et al.* (2006) reported an increase in CROM after CSM that did not depend on the side of the manipulation. Of equal importance were the findings of Dunning and Rushton (2009), who demonstrated the presence of an increase in resting biceps brachii

electromyographic activity post CSM ipsilaterally and contralaterally. This finding has been also identified by others (Suter and McMorland 2002). Consequently, the number and side of the joint restrictions were noted to determine if the effects observed had a unilateral and/or contralateral effect and whether these effects were dependent on the number of restrictions to which either CSM or MET was applied.

5.2.4 Conclusion of Demographics and Background Variables

Tables 4.2 and 4.3 demonstrate that there were no significant differences between the two groups in terms of demographics and background variables. Thus, the homogeneity of the groups would allow the changes observed to be attributed to the effect of the interventions alone.

5.3 PRIMARY DATA

5.3.1 Spinal Manipulative Therapy

5.3.1.1 Resting Muscle Activity

Small effects, involving mostly reductions in resting posterior cervical and upper trapezius muscle activity occurred following CSM applied to the cervical spine restrictions of asymptomatic participants. However, statistically significant effects were identified only for the right posterior cervical muscles (p = 0.012; paired Wilcoxon signed ranks tests). These findings provide support to previous studies demonstrating an inhibitory effect of SMT on motor activity (Herzog, Scheele and Conway 1999; Dishman and Bulbulian 2000), resulting in reductions in the activity of spinal muscles (DeVocht, Pickar and Wilder 2005; Bicalho *et al.* 2010). Furthermore, it was noted that bilateral reductions in muscle activity occurred. Thus, changes were independent of the side of manipulation, consistent with the findings of DeVocht, Pickar and Wilder (2005) and Bicalho *et al.* (2010). However, both these studies applied SMT to a single segment, and thus it was unknown whether the reductions were dependent on the number of restrictions treated. Furthermore, the paraspinal muscles of the low back were measured as opposed to the neck. Bicalho *et al.* (2010) examined paraspinal electromyographic activity during active lumbar movements, rather than at rest.

Therefore, this was the first study to demonstrate a bilateral reduction in resting posterior cervical and upper trapezius muscle activity, following a single session of CSM, independent on the number of restrictions treated.

Reductions in muscle activity following SMT are thought to result from the bombardment of afferent impulses (Korr 1975). Neurophysiologic models theorize that SMT may stimulate or modulate mechanoreceptors and proprioceptors from structures in and around the manipulated joint (Pickar 2002); mechanosensitive afferents have been identified in the zygapophyseal joints of the cervical spine (Keller and Colloca 2000; Potter, McCarthy and Oldham 2005). Subsequently, neuromuscular reflexes are evoked, as seen in the works of Herzog, Scheele and Conway (1999) and Dishman and Bulbulian (2000). The altered afferent input arising from these receptors is thought to cause changes in motoneuron excitability with subsequent reductions in muscle activity (Pickar 2002; Potter, McCarthy and Oldham 2005).

5.3.1.2 Cervical Range of Motion

Alongside the reduction in muscle activity, immediate and significant increases in cervical extension and bilateral lateral flexion were demonstrated following the application of CSM to cervical spine restrictions in asymptomatic participants ($p < 0.001$; paired Wilcoxon signed ranks tests). This was independent of the side of manipulation and the number of restrictions treated, which is consistent with the findings of Martínez-Segura *et al.* (2006). However, Martínez-Segura *et al.* (2006) utilised NP participants and only applied CSM to the dysfunctional levels of C3, C4 or C5, rather than applying CSM to any cervical levels of dysfunction in asymptomatic participants. These findings are in contrast to Branney and Breen (2012), who examined the effect of CSM on intervertebral range of flexion and extension and found a dose-related relationship between the number of manipulations received and the number of levels and directions whose intervertebral ROM increased. This could be due to the utilisation of different measurement tools (quantitative fluoroscopy screenings versus a CROM goniometer) and that the directions measured were not identical (flexion and extension only versus extension and bilateral lateral flexion).

Moreover, Branney and Breen (2012) examined these findings over a four-week period, rather than the immediate changes only.

According to Henderson (2012), intervertebral joint dysfunctions are characterized by a hypomobility of a spinal segment. Pickar (2002) adds that SMT can affect the mobility of the joint, producing alterations in the kinematic behaviour of the spine. Consequently, manipulation of the joint dysfunction produces an increase in ROM at that particular segment.

5.3.2 Muscle Energy Technique

5.3.2.1 Resting Muscle Activity

Small effects, involving mostly reductions in resting posterior cervical and upper trapezius muscle activity, occurred following the application of MET to cervical spine restrictions in asymptomatic participants. Nonetheless, none of the changes in the present study were significant. One possible explanation for this is that, unlike the cavitation associated with SMT, there is no objective measure to assess the success or accuracy of MET. The results of this study provide support to the works of Fryer and Pearce (2013), where MET applied to the L5/S1 segment was shown to decrease corticospinal and spinal reflex excitability, suggesting a decrease in motor excitability. Although Fryer and Pearce (2013) utilised asymptomatic participants, changes in central and spinal motor excitability were measured, rather than resting muscle activity. Furthermore, responses were measured using sEMG electrodes placed over the right lateral gastrocnemius muscle, as opposed to the neck musculature. Only the right gastrocnemius muscle was utilised, therefore it was unknown whether a contralateral effect took place. Thus, this study was the first to demonstrate a bilateral reduction in resting posterior cervical and upper trapezius muscle activity, independent of the side to which MET was applied.

Reductions in muscle activity following MET are thought to be the result of factors other than reflex muscle relaxation (Fryer and Pearce 2013). Increased tolerance to stretch may also play a role in the apparent increased flexibility of muscles and decreased pain perception following MET (Ballantyne, Fryer and McLaughlin 2003; Yadav and Goyal 2015). According to Phadke *et al.* (2016), when stretching and isometric contraction

occur simultaneously, there is a stimulation of muscle and joint mechanoreceptors, producing an improvement in deep segmental muscle recruitment, motor control and joint stability (Fryer and Pearce 2013).

5.3.2.2 Cervical Range of Motion

Concurrently to reductions in resting muscle activity, MET applied to cervical spine restrictions in asymptomatic participants produced an immediate and significant increase in cervical spine extension and bilateral lateral flexion ($p < 0.001$; paired Wilcoxon signed ranks tests). The results of this study are in agreement with that of Burns and Wells (2006). An immediate increase in CROM was demonstrated, following MET in asymptomatic participants, yet the restrictions were not evaluated. Thus, it is unknown whether a contralateral or unilateral effect occurred and whether the changes observed were dependent on the number of restrictions that received MET. Consequently, this study was the first to demonstrate bilateral improvements in cervical spine extension and bilateral lateral flexion following MET, independent of the number of restrictions treated.

Improved ROM following MET is thought to be the result of activation of the golgi tendon reflex. During the contraction of the muscle, the inhibitory golgi tendon reflex is activated. This reflex produces a stretch on the GTOs and a reflex relaxation of the muscle (Lenehan, Fryer and McLaughlin 2003; Ballantyne, Fryer and McLaughlin 2003). However, according to Fryer (2011), few studies have determined the neurophysiological effects of MET. Thus, factors other than reflex muscle relaxation seem responsible for the muscle extensibility and ROM following MET.

5.3.3 Spinal Manipulative Therapy Compared to Muscle Energy Technique

5.3.3.1 Resting Muscle Activity

Spinal manipulative therapy and MET produced bilateral reductions in resting posterior cervical and upper trapezius muscle activity. Table 4.9 depicts that there were no differences in treatment effect between the two groups (Mann-Whitney U tests). Thus, both groups were equally effective. Since this is the first study to compare the neurophysiological effects of SMT and MET in the neck, new knowledge is presented.

Equal treatment effects between SMT and MET in terms of muscle activity is not surprising. Although they differ in application, both are manual therapeutic interventions applied to dysfunctional joints with the aim of restoring maximum, pain free movement (Hamilton, Boswell and Fryer 2007). As previously stated, SMT and MET have been shown to be effective in the conservative management of musculoskeletal disorders, such as NP (Hurwitz *et al.* 2002; Gemmell and Miller 2006; Gross *et al.* 2010). In fact, clinical studies have compared the effects of these interventions in the treatment of NP, demonstrating measurable clinical changes in terms of pain, tenderness and ROM (Cassidy, Lopes and Yong-Hing 1992; Hamilton, Boswell and Fryer 2007; El Gendy *et al.* 2017). Accordingly, it is appropriate that the physiological mechanism behind their clinical effectiveness would be equal.

5.3.3.2 Cervical Range of Motion

Alongside reductions in resting muscle activity, significant, bilateral improvements in cervical spine extension and bilateral lateral flexion occurred in asymptomatic participants after the application of SMT or MET. As seen in Table 4.9, no differences in treatment effect were present between the two groups (Mann-Whitney U tests). This is consistent with the findings of Cassidy, Lopes and Yong-Hing (1992). Cervical spine ROM and pain intensity were measured after SMT or MET was applied to the symptomatic side of 100 participants. The results showed that both treatments increased CROM to a similar degree, but that manipulation had a significantly greater effect on pain intensity. Moreover, changes were observed on both the symptomatic (ipsilateral) side, as well as the contralateral side. However, Cassidy, Lopes and Yong-Hing (1992) utilised participants with NP that referred into the trapezius muscle, rather than asymptomatic participants. Therefore, this study compared the biomechanical effect of SMT and MET in an experimental setting. It can be concluded that although SMT and MET improve ROM through different mechanisms, the results are alike.

5.4 CONCLUSION

This study demonstrated that a single session of either CSM or MET applied to cervical spine restrictions in asymptomatic participants produced equally effective and bilateral

improvements in CROM and mostly reductions in resting posterior cervical and upper trapezius muscle activity. Thus, the null hypothesis was retained. As changes were seen in both outcomes, it demonstrates an association between joint restrictions and abnormal muscle activity. Furthermore, the concurrent occurrence of these immediate changes in both outcomes would suggest that more than one physiologic mechanism likely explains the effects exerted by SMT and MET.

CHAPTER SIX: CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The aim of this study was to determine the effect of CSM, compared to MET, on neck muscle activity and ROM in asymptomatic participants. Fifty participants were recruited for the study and divided into two groups of twenty-five each. Group 1 received CSM and Group 2 received MET.

This study showed that both CSM and MET significantly increased CROM (extension and lateral flexion bilaterally) ($p < 0.001$). Additionally, mostly reductions in resting posterior cervical and upper trapezius electromyographic muscle activity were observed following SMT and MET. However, this was only significant for the right posterior cervicals in the SMT group ($p = 0.012$). There was no evidence of a difference in treatment effect between the two interventions (Table 4.9). As a result, the null hypothesis was retained.

6.2 LIMITATIONS

This study had several limitations, such as the sample size (n = 50), firstly. Although both groups had equal treatment effects, these findings must be confirmed in a larger number of subjects.

Secondly, this was a quasi-experimental study and thus lacked a control group. A control group is used in order to quantify the effect of extraneous variables. This would have helped to ascertain the impact of the interventions alone.

Thirdly, this study was conducted using asymptomatic participants, therefore it is acknowledged that the results of the study are not applicable to symptomatic individuals.

The fourth limitation was the sEMG electrode placement. Although much effort was taken to ensure reproducibility, the exact sEMG electrode placement between participants could not be standardised or verified. In addition, the researcher was not blinded to treatment interventions and measurement readings leading to a potential bias. This was done for the sake of convenience only.

6.3 RECOMMENDATIONS

The following recommendations are made to aid future studies to further improve the data obtained from this study and allow for more statistically significant results:

- Sample size: A larger sample size should be included in this study to achieve statistically significant results in both outcomes, across both treatment groups.
- Study design:
    - This was a quasi-experimental study utilising a pre-test, post-test design. A true experimental study should be utilised in the future. True experimental studies include a control group. This will help to ascertain the impact of the interventions alone.
    - This study utilised a pre-test, post-test design to determine the immediate effect of CSM and MET. Future studies should conduct a clinical trial to determine the duration of the abovementioned changes to provide an accurate recommendation for intervals between chiropractic treatment sessions.
    - Future studies should utilise a pre-test, post-test crossover study design to strengthen the results of this study.
- Demographic variables: Future studies should include body mass and stature, and ethnicity as variables. This could be employed to classify the findings in larger samples to add valuable evidence.
- Study population:
    - This study examined an asymptomatic population. Thus, the examination of a symptomatic population with the inclusion of subjective

measurements may yield different, possibly greater, neurophysiological changes in response to the interventions.

- Exclusion criteria: Future studies should identify participants who perform regular stretching. If a person has optimal flexibility then neither intervention will improve the CROM. This factor could be included as part of the exclusion criterion for participants in the study.
- Blinding: A research assistant should be employed in future studies to conduct measurement taking or deliver the interventions to remove any potential research bias.
- Interventions: Future studies should evaluate the neurophysiological effects of various instrumented assisted SMT.

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APPENDICES

Appendix A: Permission to use the DUT Chiropractic Day Clinic

MEMORANDUM

To : Prof Adam
Chair: IREC

From : Prof A Ross
Deputy Dean: Faculty of Health Sciences

Dr Desiree Varatharajullu
Clinic Director Chiropractic Day Clinic: Chiropractic

Date : 12.03.2019

Re : Request for permission to use the Chiropractic Day Clinic for research purposes

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Permission is hereby granted to :

Miss Sasha Lee King (Student Number: 21355311)

Research title : "The effect of cervical spine manipulation compared to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants"

Miss King, is requested to submit a copy of her FRC / IREC approved proposal along with proof of her M.Tech:Chiropractic registration to the Clinic Administrators before she starts with her research in order that any special procedures with regards to her research can be implemented prior to the commencement of her seeing patients.

Thank you for your time.

Kind regards

Prof AHA Ross
Deputy Dean
Faculty of Health Sciences

Dr Desiree Varatharajullu
Clinic Director: Chiropractic Day Clinic:
Chiropractic

Cc: Mrs Linda Twiggs: Chiropractic Day Clinic
Dr A. Abdul-Rasheed: Research co-ordinator
Dr A. Docrat and Dr A. Abdul-Rasheed: Research supervisors

Appendix B: Permission to conduct research at DUT

Directorate for Research and Postgraduate Support
Durban University of Technology
Tromso Annexe, Steve Biko Campus
P.O. Box 1334, Durban 4000
Tel.: 031-3732576/7
Fax: 031-3732946

08th April 2019

Ms Sasha Lee King
c/o Department of Chiropractic and Somatology
Faculty of Health Sciences
Durban University of Technology

Dear Ms King

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers. I am pleased to inform you that the Institutional Research and Innovation Committee (IRIC) has granted full permission for you to conduct your research "The effect of cervical spine manipulation compared to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants" at the Durban University of Technology.

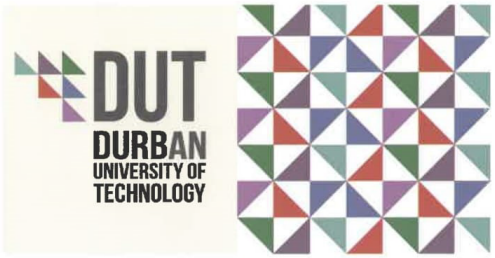
The DUT may impose any other condition it deems appropriate in the circumstances having regard to nature and extent of access to and use of information requested.

We would be grateful if a summary of your key research findings can be submitted to the IRIC on completion of your studies.

Kindest regards.
Yours sincerely

_____
PROF CARIN NAPIER
DIRECTOR (ACTING): RESEARCH AND POSTGRADUATE SUPPORT DIRECORATE

Appendix C: IREC approval



Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

11 April 2019

Ms S L King
P O Box 21341
Bluff
4036

Dear Ms King

The effect of cervical spine manipulation compared to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants

The Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letters.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

Professor J K Adam
Chairperson: IREC

Appendix D: Clinical trial registration

10 June 2019

To Whom It May Concern:

RE: The effect of cervical spine manipulation compared to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants

As project manager for the Pan African Clinical Trial Registry (www.pactr.org) database, it is my pleasure to inform you that your application to our registry has been accepted. Your unique identification number for the registry is **PACTR201906557214661**.

Please be advised that your trial is registered under an initiative within our system that allow us to capture data of trials that are already in progress or completed. As such, your trial registration may not adhere to the mandates set forth by the International Committee of Medical Journal Editors for registration requirements, and it is your duty to be transparent to any journal that may ask about the retrospective status of your registration.

Please note you are responsible for updating your trial, or for informing us of changes to your trial. Additionally, please provide us with copies of your ethical clearance letters as we must have these on file (via email or post or by uploading online) at your earliest convenience if you have not already done so.

Please do not hesitate to contact us at +27 21 938 0835 or email epienaar@mrc.ac.za should you have any questions.

Yours faithfully,

Elizabeth D Pienaar
www.pactr.orgProject Manager
+27 021 938 0835

The South African Medical Research Council
Cochrane South Africa | PO Box 19070, Tygerberg, 7505
Tel: +27 (0)21 938 0438 | Email: cochrane@mrc.co.za | Web: www.southafrica.cochrane.org

Appendix E: Letter of information and informed consent

LETTER OF INFORMATION

Title of the Research Study: The effect of cervical spine manipulation compared to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants.

Principal Investigator/s/researcher: Sasha Lee King [BTech: Chiropractic]

Co-Investigator/s/supervisor/s: Dr. Aadil Docrat [M. Tech: Chiropractic, M.Med.Sci, P.G.Dip:UT]
Dr. Ashura Abdul-Rasheed [MTech: Chiropractic]

Brief Introduction and Purpose of the Study: This research study aims to determine the effect of cervical spine manipulation compared to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants. 50 people will be required to complete this study.

Outline of the Procedures:
If you agree to take part in this research, you will have to sign an informed consent form. The researcher will then take a case history and a physical examination and cervical spine regional examination will be conducted. This is to determine if you meet the inclusion criteria of the study. If you do, you will then be assigned to one of two treatment groups. You will then be asked to remove any clothing covering the neck and upper back area and appropriate clothes (clinic gown for females) will be provided. A record of the baseline sEMG and CROM device readings will be obtained by the researcher. For the sEMG, you may be required to remove any hair present over the neck and upper back region for the placement of electrodes in those areas. For the CROM device this will involve the placement and strapping of a measurement tool on your head. Treatment will then be administered according to group allocation. If you are in the cervical manipulation group, then you will receive a cervical spine manipulation. If you are in the muscle energy technique group, then this is will be applied to your neck for 5 seconds three times. Readings (sEMG and CROM) will be then be taken again straight after the intervention.

Risks or Discomforts to the Participant: The treatment given to you will be under the supervision of a qualified chiropractor at all times. Spinal manipulative therapy and muscle energy technique (one of the interventions you will be receiving) are non-invasive forms of manual therapy and are safe treatments.

Benefits: You will benefit from the study by receiving treatment and I, the researcher, will benefit by completing my dissertation and publishing it.

Reason/s why the Participant May Be Withdrawn from the Study: If you suffer any adverse reactions and wish to withdraw from the study, you are free to do so. If you are not compliant with what is expected of you during the course of this study, you will be withdrawn. You are free to withdraw from the study at any time. Withdrawal will not prevent you from receiving further treatment at the Chiropractic Day Clinic at normal clinic rates.

Remuneration: There will be no form of remuneration offered to you for taking part in the study.
Costs of the Study: You will not be expected to contribute to any costs of the study.

Confidentiality: All your medical records will be kept confidential and will be stored in the Chiropractic Day Clinic for 5 years, after which it will be shredded and electronic data will be deleted. Your name will not appear on any of the data sheets or thesis.

Research-related Injury: There are no foreseeable injuries occurring with this study. There will be no compensation in the event of an injury.

Persons to Contact in the Event of Any Problems or Queries:
Please contact the researcher, Sasha Lee King on 0828964915, my supervisor, Dr. A. Docrat on 0313732589, my co-supervisor, Dr. A. Abdul-Rasheed on 0605062394 or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support, Prof. C. Napier on 031 373 2326 or carinn@dut.ac.za

Yours sincerely,

Sasha Lee King
Researcher

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Sasha Lee King, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: _____,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

_____	_____	_____	_____
Full Name of Participant	**Date**	**Time**	**Signature / Right Thumbprint**

I, Sasha Lee King hherewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Sasha Lee King	_____	_____
Full Name of Researcher	**Date**	**Signature**
_____	_____	_____
Full Name of Witness (If applicable)	**Date**	**Signature**
_____	_____	_____
Full Name of Legal Guardian (If applicable)	**Date**	**Signature**

I-Aphendiksi u-E

INCWADI YOLWAZI

Isihloko socwaningo/ sophenyo: Umthelela wokwelulwa kwentamo/ komqala uma kuqhathaniswa namasu amandla emasela/ emisipha ekusebenzeni kwamamasela entamo kanye nasekunyakazeni kumbe ekujikelezeni kwayo kulabo ababambe iqhaza futhi abangenaso isigulo/ izinhlungu.

Umphenyi/ umcwaningi omkhulu: USasha Lee King [i-BTech: yeKhayirophrakthikhi]

Abaphathi/ ababhekeleli bocwaningo: UDkt. u-Aadil Docrat [i-M. Tech: yeKhayirophrakthikhi, iM.Med.Sci, P.G.Dip: UT]
UDkt. u-Ashura Abdul-Rasheed
[i-MTech: yeKhayirophrakthikhi]

Isingeniso kafushane kanye nenhloso yocwaningo/ yophenyo:
Lolu cwaningo luhlose ukuthi luveze umthelela wokwelulwa kwentamo/ komqala uma kuqhathaniswa namasu amandla emasela/ emisipha ekusebenzeni kwamamasela entamo kanye nasekunyakazeni kwayo kulabo ababambe iqhaza futhi abangenaso isigulo/ izinhlungu. Kuzodingeka amalunga angama-50 ukuze kuphothulwe lolu cwaningo.

Uhlaka lwenqubo yocwaningo/ yophenyo:
Uma uvuma ukubamba iqhaza kulolu cwaningo, kuzomele ukuthi usayine ifomu lesivumelwano esicatshangisisiwe. Umcwaningi ke uzobe esethatha umlando wakho omayelana nesigulo, bese ke ekuxilonga wena siqu sakho jikelele aphinde akuhlole nentamo ngokugcwele. Lokhu kwenzelwa ukuthi kubonakale ngohla lokhetho lwalolu cwaningo ukuthi uyafaneleka yini ukuthi ube yilunga. Uma kuwukuthi uyafaneleka, uzobe sewufakwa ohlotsheni olulodwa lokwelapha kulezi ezimbili ezizobe zisetshenziswa emaqenjini amabili ahlukene alolu phenyo. Uzobe sowucelwa ukuthi ususe okanye ukhumule konke lokho okwembethe/ okugqokile okumboze intamo kanye nomzimba/ nengenhla lomhlane, kanti izingubo ezifanelekile nezisetshenziswa emtholampilo (igawoni/ ingubo yasemtholampilo kwabesimame) zizohlinzekwa. Umphenyi uzobe esethatha isisekelo sokuqala sezilinganiso ezikala ngamadivayisi i-sEMG kanye ne-CROM. Mayelana ne sEMG, kungenzeka kudingakale ukuthi ugunde bonke uboya/ izinwele ezikhona entanyeni kanye nasemhlane (maphezulu) ukuze kubekwe kahle ama-elekthrodi kulezo zindawo. Idivayisi le CROM lona lizohlanganisa ukunamathiselwa/ ukuboshelwa kwethuluzi lokukala okanye lokumeja ekhanda lakho. Uzobe sewuyelashwa ke ngendlela yeqembu ofakwe kulo. Uma useqenjini lalabo abazokwelulwa intamo, uzobe sewuyelulwa ke intamo ngendlela yakhona. Uma useqenjini lalabo abazokwelashwa ngokusetshenziswa kwamasu amandla emasela/ emisipha athize, kuzobe sekubekwa okanye sekuxhunywa leli divayisi entanyweni yakho amasekhendi ay-5 ngokuphindelela kuze kube ka-3. Kuzobe sekuphindwa futhi kuthathwa imibhalo noma amamejamenti (e-sEMG kanye neCROM) emva kokwelashwa kwakho.

Ubungozi noma Ukuphazamiseka kukambambiqhaza: Kuzobe kukhona iKhayirophraktha/ udokotela wamathambo ozobe ekhona eqaphe ukwelashwa kwakho zikhathi zonke. Ukwelulwa kwentamo kanye namasu amandla emasela/ emisipha (okukodwa kwakho ozokuthola) akuzona izindlela ezilimazayo zokwelapha kanti futhi ziphephile kakhulu.

Inzuzo: Wena ngokubamba iqhaza kulolu cwaningo uzozuza ukwelashwa kanti mina, mcwaningi, ngizozuza ngokuthi ngiphothule incwadi yami yezocwaningo bese ngiyayishicilela ukuthi ibonwe yizwe lonke.

Izizathu ezingenza ukuthi umbambiqhaza ahoxiswe ekubambeni iqhaza kulolu phenyo: Uma kwenzeka uzwa unokungazizwa kahlehle okwenza ufise ukuhoxa ekubambeni iqhaza kulolu cwaningo, uvumelekile ngenkululeko ukwenzenjalo. Uma ungathobeli umthetho okanye ungenzi lokho okulindelekile kuwe okumayelana nalolu cwaningo, uzokhishwa kulolu cwaningo. Ukhululekile futhi uvumelekile ukuhoxa ekubambeni iqhaza kulolu cwaningo nganoma yisiphi isikhathi. Ukuhoxa kwakho ekubambeni iqhaza kulolu cwaningo angeke kudale ukuthi ungabe usathola ukwelashwa emtholampilo weKhayirophrakthikhi ngamanani akhona ajwayelekile.

Umkomelo/ umholo: Angeke kube khona mholo okanye mali ozoyinikezwa ngokubamba iqhaza kulolu cwaningo.

Inani elikhokhwa umbambiqhaza wocwaningo/ wophenyo: Ayikho imali ozoyikhokha ngokuhlanganyela okanye ngokubamba kwakho iqhaza kulolu cwaningo.

Ubumfihlo: Wonke amarekhodi aphathelene nokwelashwa kwakho azogcinwa eyimfihlo futhi evalelwe emtholampilo weKhayirophrakthikhi iminyaka ey-5, bese kuthi emuva kwalokho azobe eseyahlaphazwa/ enziwa izimvithi kanti ama-elekthronikhi khophi nawo azobe esecishwa. Igama lakho angeke lishicilelwe kwidatha shithi okanye kwincwadi yami yezocwaningo.

Ukulimala okuphathelene nocwaningo/ nophenyo: Akukho ukulimala okubonakala kungase kwenzeke ngenxa/ okumayelana nalolu cwaningo. Asikho isinxephezelo ozosithola uma kwenzeka ulimala.

Abantu ongaxhumana nabo uma unezinkinga okanye unemibuzo:
Uyacelwa ukuthi uxhumane nomcwaningi, uSasha Lee King ku 082 896 4915, umphathi wami omkhulu, uDkt. A. Docrat ku 031 373 2589, umphathi wami owumlekeleli uDkt. A. Abdul-Rasheed ku 060 506 2394 noma Umlawuli wezimiso zokuhle kwezocwaningo weSikhungo ku 031 373 2375. Izinkonondo okanye izikhalazo zingadluliselwa kuMphathi/uMqondisi: Wesisekelo seZocwaningo, uSolwazi C. Napier ku 031 373 2326 noma ku carinn@dut.ac.za

Yimi ozithobayo,

USasha Lee King
Umcwaningi/ umphenyi

IMVUME

Isitatimende semvumelwano yokubamba iqhaza kucwaningo/ kuphenyo:

- Mina ngiyaqinisekisa ukuthi umcwaningi; **uSasha Lee King** ungazisile ngenkambo, uhlobo, inzuzo kanye nobungozi balolu cwaningo- Inombolo yezimiso zokuhle yocwaningo: _____.
- Ulwazi kanye nencazelo emayelana nalolu cwaningo ebhalwe lapha ngenhla (Incwadi Yolwazi kaMbambiqhaza) nayo ngiyitholile, ngayifunda futhi ngayiqondisisa.

- Ngiyaqonda ukuthi imiphumela yocwaningo, okubala imininingwane yami yobulili, iminyaka, usuku lokuzalwa, ama-inishiyali nokuthi ngiphethwe yini kuzosetshenziswa ngokungaziwa/ ngobumfihlo ukuze kwenziwe umbiko wocwaningo.

- Ngokubona izidingo zocwaningo, mina ngiyavuma ukuthi imininingwane yami etholakale kulolu cwaningo isetshenziswe ngu mcwaningi ohlelweni lwekhompiyutha.

- Ngingakwazi, kunoma yisiphi isigaba, ukuthi ngihoxise imvume nokubamba kwami iqhaza kulolu cwaningo ngale kwengcindezi.
- Ngibe nethuba elanele lokubuza imibuzo futhi (ngokuzikhethela/ ngokuzithandela kwami) ngiyafunga ukuthi ngikulungele ukubamba iqhaza kulolu cwaningo.

- Ngiyaqonda ukuthi lolo lwazi olusha, olubalulekile futhi oluthintana nokubamba kwami iqhaza ngenkathi kwenziwa lolu cwaningo ngizovumeleka ukulwazi.

_____	_____	_____	_____	
Igama eliphelele loMbambiqhaza sakwisandla sokudla	**Usuku**	**Isikhathi**	**Isiginisha**	**/Isithupha**

Mina, Sasha Lee King ngiyaqinisekisa ukuthi lo mbambiqhaza ongenhla uchazeliwe kabanzi ngohlobo, inkambo kanye nobungozi balolu cwaningo olungenhla.

Sasha Lee King	_____	_____
Igama eliphelele loMcwaningi	**Usuku**	**Isiginisha**
_____	_____	_____
Igama eliphelele likaFakazi (Uma kufanelekile)	**Usuku**	**Isiginisha**
_____	_____	_____
Igama eliphelele loMnakekeli Osemthethweni (Uma kufanelekile)	**Usuku**	**Isiginisha**

Appendix F: Power analysis

-- Wednesday, November 07, 2018 -- 20:26:57

F tests – ANOVA: Repeated measures, within factors

Analysis:	Post hoc: Compute achieved power		
Input:	Effect size f	=	0.25
	α err prob	=	0.05
	Total sample size	=	100
	Number of groups	=	2
	Number of measurements	=	4
	Corr among rep measures	=	0.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	50.0000000
	Critical F	=	2.6353131
	Numerator df	=	3.0000000
	Denominator df	=	294
	Power (1-β err prob)	=	0.9999957

[2] *-- Wednesday, November 07, 2018 -- 20:27:13*

F tests – ANOVA: Repeated measures, within factors

Analysis:	Post hoc: Compute achieved power		
Input:	Effect size f	=	0.25
	α err prob	=	0.05
	Total sample size	=	50
	Number of groups	=	2
	Number of measurements	=	4
	Corr among rep measures	=	0.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	25.0000000
	Critical F	=	2.6674431
	Numerator df	=	3.0000000
	Denominator df	=	144
	Power (1-β err prob)	=	0.9919398

[3] *-- Wednesday, November 07, 2018 -- 20:33:21*

F tests – ANOVA: Repeated measures, between factors

Analysis:	Post hoc: Compute achieved power		
Input:	Effect size f	=	0.3942857
	α err prob	=	0.05
	Total sample size	=	50
	Number of groups	=	2
	Number of measurements	=	27
	Corr among rep measures	=	0.5
Output:	Noncentrality parameter λ	=	14.9909027
	Critical F	=	4.0426521
	Numerator df	=	1.0000000
	Denominator df	=	48.0000000
	Power (1-β err prob)	=	0.9666195

[4] *-- Wednesday, November 07, 2018 -- 20:33:42*

F tests – ANOVA: Repeated measures, between factors

Analysis:	Post hoc: Compute achieved power		
Input:	Effect size f	=	0.3942857
	α err prob	=	0.05
	Total sample size	=	50

Number of groups		=	2
	Number of measurements	=	27
	Corr among rep measures	=	0.8
Output:	Noncentrality parameter λ	=	9.6271852
	Critical F	=	4.0426521
	Numerator df	=	1.0000000
	Denominator df	=	48.0000000
	Power (1−β err prob)	=	0.8599658

[5] *-- Wednesday, November 07, 2018 -- 20:37:04*

F tests – ANOVA: Repeated measures, between factors

Analysis:	Post hoc: Compute achieved power		
Input:	Effect size f	=	0.1428571
	α err prob	=	0.05
	Total sample size	=	50
	Number of groups	=	2
	Number of measurements	=	27
	Corr among rep measures	=	0.8
Output:	Noncentrality parameter λ	=	1.2638075
	Critical F	=	4.0426521
	Numerator df	=	1.0000000
	Denominator df	=	48.0000000
	Power (1−β err prob)	=	0.1964978

[6] *-- Wednesday, November 07, 2018 -- 20:38:11*

F tests – ANOVA: Repeated measures, between factors

Analysis:	Post hoc: Compute achieved power		
Input:	Effect size f	=	0.1428571
	α err prob	=	0.05
	Total sample size	=	50
	Number of groups	=	2
	Number of measurements	=	2
	Corr among rep measures	=	0.8
Output:	Noncentrality parameter λ	=	1.1337862
	Critical F	=	4.0426521
	Numerator df	=	1.0000000
	Denominator df	=	48.0000000
	Power (1−β err prob)	=	0.1810673

[7] *-- Wednesday, November 07, 2018 -- 20:39:49*

F tests – ANOVA: Repeated measures, between factors

Analysis:	Post hoc: Compute achieved power		
Input:	Effect size f	=	0.3942857
	α err prob	=	0.05
	Total sample size	=	50
	Number of groups	=	2
	Number of measurements	=	2
	Corr among rep measures	=	0.8
Output:	Noncentrality parameter λ	=	8.6367341
	Critical F	=	4.0426521
	Numerator df	=	1.0000000
	Denominator df	=	48.0000000
	Power (1−β err prob)	=	0.8211098

Appendix G: Advertisement

BETWEEN THE AGES OF 18-35
WITH NO NECK PAIN?

DO YOU WANT TO BE INVOLVED IN INTERESTING RESEARCH USING EXCITING EQUIPMENT?

YOUR NECK WILL BE ASSESSED AND YOU COULD RECEIVE FREE TREATMENT!

Contact Sasha Lee King (0828964915) or the DUT Chiropractic Clinic (031 3732511) for more information.

INGABE UNEMINYAKA EYI-18
KUYA KUMA-35 FUTHI AWUNABO
UBUHLUNGU BENTAMO/ BOMQALA?

UYAFUNA UKUBAMBA IQHAZA KUCWANINGO OLUTHAKAZELISAYO NOLUNENTSHISEKELO KANTI FUTHI OLUSEBENZISA UHLOBO OLUTHIZE LWAMATHULUZI NOMA LWEMISHINI?

INTAMO YAKHO IZOXILONGWA/ IZOHLOLWA BESE WENA UBA SEMATHUBENI OKUTHOLA UKWELASHWA KWAMAHHALA!

Xhumana noSasha Lee King (082 896 4915) noma umtholampilo wamathambo/ weKhayirophrakthikhi wase DUT(031 373 2511) ukuze uthole ulwazi oluphelele/ olugcwele.

Appendix H: Permission to place advertisements

[Date]

Request for Permission to Place Advertisements

Dear Sir/Madam

My name is Sasha Lee King, a MTech: Chiropractic student at the Durban University of Technology. The research I wish to conduct for my master's dissertation involves The effect of cervical spine manipulation compared to muscle energy technique on neck muscle activity and range of motion in asymptomatic participants.

I am hereby seeking your consent to place an advertisement, which is attached, on your premises to recruit participants for my research.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the approval letter which I received from the Institutional Research Ethics Committee (IREC).

If you require any further information, please do not hesitate to contact me [0828964915; sashalee.splasha@gmail.com]. Thank you for your time and consideration in this matter.

Yours sincerely,

Sasha Lee King
Durban University of Technology

Appendix I: Surface electromyographic readings

Surface electromyographic readings

Participant's code: _____
Group no.: ____

SURFACE ELECTROMYOGRAPHIC READINGS				
		Pre-intervention	**Post-intervention**	**Change**
Posterior cervicals	**Right**			
	Left			
Upper trapezius	**Right**			
	Left			

Appendix J: CROM goniometer readings

CROM Goniometer readings

Participant's code: ____
Group no.: ____

CROM GONIOMETER READINGS				
		Pre-intervention	**Post-intervention**	**Change**
Extension				
Lateral Flexion	**Right**			
	Left			

Appendix K: Case history

DUT DURBAN UNIVERSITY OF TECHNOLOGY — DEPARTMENT OF CHIROPRACTIC

CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: _____ Date: _____

File #: _____ Age: _____

Gender: _____ Occupation: _____

Student: _____ Signature _____

FOR CLINICIANS USE ONLY:

Initial visit

Clinician: Signature:

Case History:

Examination:
Previous: Current:

X-Ray Studies:
Previous: Current:

Clinical Path. lab:
Previous: Current:

CASE STATUS:

PTT:	Signature:	Date:

CONDITIONAL:
Reason for Conditional:

Signature: Date:

Conditions met in Visit No: Signed into PTT: Date:

Case Summary signed off: Date:

Student's Case History:

1. **Source of History:**

2. **Chief Complaint: (patient's own words):**

3. **Present Illness:**

	Complaint 1(principle complaint)	**Complaint 2 (additional or secondary complaint)**
Location Onset : Initial: Recent: Cause: Duration Frequency Pain (Character) Progression Aggravating Factors Relieving Factors Associated S & S Previous Occurrences Past Treatment Outcome:		

4. **Other Complaints:**

5. **Past Medical History:**

General Health Status

Childhood Illnesses

Adult Illnesses

Psychiatric Illnesses

Accidents/Injuries

Surgery

Hospitalizations

6. Current health status and life-style:

Allergies

Immunizations

Screening Tests incl. x-rays

Environmental Hazards (Home, School, Work)

Exercise and Leisure

Sleep Patterns

Diet

Current Medication
Analgesics/week:
Other (please list):

Tobacco
Alcohol
Social Drugs

7. Immediate Family Medical History:

Age of all family members
Health of all family members
Cause of Death of any family members

	Noted	Family member		Noted	Family member
Alcoholism			Headaches		
Anaemia			Heart Disease		
Arthritis			Kidney Disease		
CA			Mental Illness		
DM			Stroke		
Drug Addiction			Thyroid Disease		
Epilepsy			TB		
Other (list)					

8. Psychosocial history:

Home Situation and daily life
Important experiences
Religious Beliefs

9. Review of Systems (please highlight with an asterisk those areas that are a problem for the patient and require further investigation)

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

Appendix L: Senior physical

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC

PHYSICAL EXAMINATION: SENIOR

Patient Name: _____				**File no:** _____	**Date:** _____
Student:		**Signature:**			
VITALS:					
Pulse rate:				Respiratory rate:	
Blood pressure:	R	L		Medication if hypertensive:	
Temperature:				Height:	
Weight:	Any recent change?	Y / N	If Yes: How much gain/loss		Over what period
GENERAL EXAMINATION:					
General Impression					
Skin					
Jaundice					
Pallor					
Clubbing					
Cyanosis (Central/Peripheral)					
Oedema					
Lymph nodes	Head and neck				
	Axillary				
	Epitrochlear				
	Inguinal				
Pulses					
Urinalysis					
SYSTEM SPECIFIC EXAMINATION:					
CARDIOVASCULAR EXAMINATION					
RESPIRATORY EXAMINATION					
ABDOMINAL EXAMINATION					
NEUROLOGICAL EXAMINATION					
COMMENTS					
Clinician:			**Signature:**		

Page 1

Appendix M: Cervical spine regional

REGIONAL EXAMINATION – CERVICAL SPINE

Patient: ..... File No: .....

Date: ..... Student: .....

Clinician: ..... Sign: .....

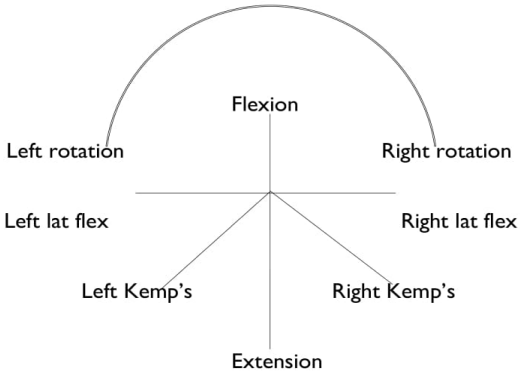
OBSERVATION:

Posture
Swellings
Scars, discolouration
Hair line
Body and soft tissue contours

Shoulder position
Left:
Right:
Shoulder dominance (hand):
Facial expression:

RANGE OF MOTION:

Extension (70°):
L/R Rotation (70°):
L/R Lat flex (45°):
Flexion (45°):



PALPATION:

Lymph nodes
Thyroid Gland
Trachea

MYOFASCIAL ASSESSMENT

Tenderness		Right	Left
Trigger Points:	SCM		
	Scalenii		
	Post Cervicals		
	Trapezius		
	Lev scapular		

ORTHOPAEDIC EXAMINATION:

	Right	Left		Right	Left
Adson's test			Halstead's test		
Brachial plexus test			Hyper-abduction test		
Cervical compression			Kemp's test		
Cervical distraction			Lateral compression		
Costoclavicular test			Lhermitte's sign		
Dizziness rotation test			Shoulder abduction test		
Doorbell sign			Shoulder compression test		
Eden's test					

NEUROLOGICAL EXAMINATION:

Dermatones	**Left**	**Right**	**Myotomes**	**Left**	**Right**	**Reflexes**	**Left**	**Right**
C2			C1			C5		
C3			C2			C6		
C4			C3			C7		
C5			C4					
C6			C5					
C7			C6					
C8			C7					
T1			C8					
			T1					

Cerebellar tests:	Left	Right
Dysdiadochokinesis		

VASCULAR:	**Left**	**Right**		**Left**	**Right**
Blood pressure			Subclavian arts.		
Carotid arts.			Wallenberg's test		

MOTION PALPATION & JOINT PLAY:

Left: Motion Palpation:
Joint Play:
Right: Motion Palpation:
Joint Play:

BASIC EXAM: SHOULDER:

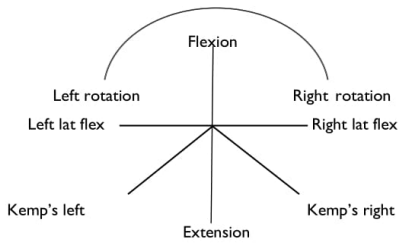
Case History:

ROM: Active:
Passive:
RIM:
Orthopaedic:
Neuro:
Vascular:

BASIC EXAM: THORACIC SPINE:

Case History:

ROM:



Motion Palpation:	
Orthopaedic:	
Neuro:	
Vascular:	
Observ/Palpation:	
Joint Play:	

Appendix N: SOAPE note

DUT DURBAN UNIVERSITY OF TECHNOLOGY — DEPARTMENT OF CHIROPRACTIC

Patient Name:		***File number:***	***Page:***
Date:	***Visit:***	***Student:***	
Attending Clinician:		***Signature:***	
S: ***Numerical Pain Rating Scale (Patient)*** Least ***0 1 2 3 4 5 6 7 8 9 10*** Worst		***Student Rating*** ☐	***A:***
0:			***P:***
			E:
Special attention to:			***Next appointment:***
EBCC References:			
Date:	***Visit:***	***Student:***	
Attending Clinician:		***Signature:***	
S: ***Numerical Pain Rating Scale (Patient)*** Least ***0 1 2 3 4 5 6 7 8 9 10*** Worst		***Student Rating*** ☐	***A:***
O:			***P:***
			E:
Special attention to:			***Next appointment:***
EBCC References:			